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THE METABOLISM OF ORGANIC AND INORGANIC COMPOUNDS OF PHOSPHORUS

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THE METABOLISM OF ORGANIC AND INORGANIC PHOSPHORUS COMPOUNDS

This comparison of the nutritive values of several compounds of phosphorus was undertaken as a part of a general study of mineral metabolism in relation to the practical feeding of human beings and animals. In beginning this general program of investigation attention was given first to compounds of phosphorus, since this element is the one which is used in the greatest diversity of compounds and at the same time in large proportion to the total mineral requirement.

In the selection of compounds of phosphorus for comparison in this work it was our idea to include representatives of as many as possible of the groups of those compounds which are used in prominent ways either in foods or in drugs; phosphates as that form in which, because of cheapness and accessibility, one would be most likely to use phosphorus for supplementary purposes in live-stock feeding; hypophosphites because of their popularity in the trade in medicines for human beings; nucleic acid because of the physiological significance of phosphorus in this form in living organisms; phytin as an especially abundant phosphorus compound of cereals; and glycerophosphates as constituents of the lecithins, which are universal cell-constituents. Interest also attaches to these several compounds because of their variability in foods as affected by conditions of growth or methods of preparation or manufacture. Neither lecithin nor phosphoprotein was included in this investigation. A study of the literature of phosphorus metabolism, conducted during the course of these experiments, reveals more evidence in favor of superior nutritive values of lecithins and phosphoproteins than of

any of the compounds included in this investigation.* Our inclusion of glycerophosphates, because of the fact that much of the phosphorus of lecithin is absorbed in this form, seems to have been beside the point in that the specific effects of lecithin appear to be due to that portion which is absorbed directly, without cleavage, or at least not to be due to that portion which is absorbed as glycerophosphate.

In recognition of the many differences which exist in the composition of natural foods, and the impossibility, therefore, of ascribing any given nutritive effect to any particular food constituent, this series of experiments was conducted with standard basal rations composed, in the main, from comparatively simple manufactured products of plant and animal origin to which the phosphorus compounds of interest were added in the form of approximately pure chemicals. The logical justification of this procedure appears at first glance unquestionable, but an experience of several years with such rations leads us to the belief that as bearing on the nutritive values of the same phosphorus compounds in their natural chemical and physical relationships in normal foods, the results obtained with these synthetic rations can not be applied without discount and with assurance that they exactly represent the facts.

In short, from the nature of the case it seems likely that a measure of uncertainty must continue to exist regarding the reasons for certain of the specific effects of foods, since we are lacking in assurance that in the isolation of a compound of interest its chemical composition, its course in metabolism, and its nutritive effect are the same as in its natural physical and chemical relationships.

The beginning of this study at the Ohio Station was made possible in the winter of 1907-8 by the creation of the Department of Nutrition. No work of this character having been done previously at this institution it was necessary gradually to accumulate the needed apparatus and facilities during the course of the investigation. Naturally, the results reflect the conditions under which the work was accomplished, and there is from each experiment to the next a decided improvement in the quality of the data, a fact which may not be apparent to the reader but which may be kept in mind in the weighing of the evidence presented. Many problems of technique and of chemical analysis have also required solution as we progressed in this study, and the removal of each of these obstacles has contributed toward the improvement of the work. The fifth and last experiment herein recorded was performed under very favorable circumstances.

*For a general review of the literature of phosphorus metabolism the reader is referred to Tech. Bul. 5, Ohio Agr. Exp. Sta.

The first lot of pigs purchased for this work in the fall of 1907 were put at once on a low-phosphorus ration of pearl hominy (corn minus the skin and the germ) and blood flour, the object being so to reduce the store of phosphorus available within the animal for the making good of deficiencies in the ration that the pigs would be sensitive to differences in the nutritive value of the various compounds of phosphorus to be administered, it being the plan, after a period of feeding on this basal ration, to add different phosphorus compounds to the food of each pig, and, by the method of the metabolism experiment, to compare their nutritive values. The pigs ate this ration with the greatest relish. They weighed about 110 pounds each, and ate about 6 pounds each, per day, of this feed. They soon began to feel the effects of the deficiency of these foods in calcium and phosphorus, however, and their appetites decreased accordingly.

In general we have found that in time pigs lose appetite for foods which induce abnormal states of nutrition, even though these foods have been very palatable at first; and also, conversely, that foods which at first are not much relished by pigs will in time come to be eaten with the greatest eagerness if they be such as contribute to the pigs' state and feeling of well-being.

By the time we were ready to start the experiment, about six weeks after the beginning of the preliminary feeding, the pigs were no longer willing to cooperate. Generous feeding on a low-ash ration had induced such a state of debility that it was thought best to send these pigs to market, and to begin again. In our subsequent experience with this and other similar, palatable, low-ash rations we have found it necessary so to restrict the food allowance at the beginning that the pigs would not fail to eat it later, and to cut down the preliminary feeding on the low-phosphorus basal ration to as short a term as consistent with the getting of correct initial weights, since it became apparent that to keep the pigs alive and hearty on such a ration during the desired period was a problem requiring the closest of attention. It is possible to keep pigs alive almost indefinitely on such rations but we are doubtful of the value, in the practical feeding of healthy farm stock, of results obtained from animals in abnormal states of nutrition, and it has been our attempt all the way through this study to draw our conclusions and to terminate our experiments before the deficiencies of the foods have produced such deformities and derangements in the pigs as might fairly be considered to cast doubt on the value of their performance as guides to the feeding of healthy animals. Who knows

but that the organism *in extremis* may possess capacities which it either has not or does not use in normal states of nutrition? .

Our second start in this work was with five cross-bred Berkshire-Chester White pigs, all from the same litter. Each pig was put into a close crate in which it was given food in a removable zinc trough. The urine was voided through a rubber funnel into a receptacle beneath the crate, and the feces were collected in a rubber bag, these appliances being held in place by a harness of light leather straps. This apparatus served the intended purpose perfectly except for the facts that its use seemed to entail an undesirable rigidity of confinement of the pig and excessive labor on the part of the single attendant. The harnesses were therefore discarded, and the crates were revised in such manner that the pig urinated into a pan beneath the crate, and defecated onto a zinc-covered surface in the floor of the crate. The urine pan was placed under a coarse screen in the floor of the crate, and foreign matter was excluded from the sample by the use of a fine cotton cloth stretched over a light screen held in place within the pan by lugs soldered onto its sides. The pigs were kept in place in the crates by two removable iron rods running from side to side behind them, and also by wooden strips which regulated the width of the space available by being nailed lengthwise, inside of the crate, at the height of the middle of the pig's sides when standing. The front of the crate was constructed as a gate, hinged at the bottom so as to form an incline upon which the pig could descend to the floor when it was opened. A square hole in the middle of the bottom of this front door provided for the added length of the pig when lying down by giving him a place for his nose. This close confinement was necessary to the perfect collection of the excreta. Liberal use of soap, water and disinfectants externally, and laxatives and anthelmintics internally served to prepare the pigs for the investigation. Under these conditions the third and last start of the experiment was made.

EXPERIMENT I

This experiment was conducted in April and May, 1908, and consisted of a metabolism experiment comparing phosphates, glycerophosphates, hypophosphites and nucleic acid. Four pigs were used. The phosphates, glycerophosphates and hypophosphites were, in each case, mixtures of salts of sodium, potassium, calcium, magnesium and iron. The nucleic acid was from yeast. The basal ration consisted of pearl hominy (corn minus the skin and the germ), blood albumen, wheat gluten and salt, with the addition of small amounts of senna when necessary. The experimental periods

were 10 days each in length. The feces were marked by the feeding of small indigestible seeds. Carmine is a better marker and was used in the later work.

It was found that under our conditions of feeding and confinement of the pigs the food would pass through them in 48-72 hours, but that after the first appearance of a given food-residue appreciable quantities of the same continued to appear during the three following days.

Thymol was used in the urine pans to prevent fermentation. These pans were emptied once daily, then rinsed out with distilled water, which was added to the sample, and afterward were sterilized by heat before being returned to the digestion crates. The cloths used to exclude foreign matter from the urines were extracted and rinsed with hot distilled water, and the leachings also added to the urine sample.

The pigs were exercised twice daily for 15 minutes at a time. This seemed to be sufficient, as they often jumped back into the crates, and went to sleep, before the expiration of their period of freedom.

Pigs are omnivorous, and when kept on a restricted or abnormal ration will gnaw wood with great industry. No wood should be within reach during such studies. With their sharp incisors these pigs even tore the solder from the galvanized iron floor, drew the nails and ripped up the sheets of metal.

The two pigs which withstood this routine longest showed a greater disposition than others to play when given their liberty. After a few weeks' confinement the pigs had to be kept as quiet as possible during exercise, especially on cool days, so as to prevent injury. They became "cagy" and much inclined to "stampede."

A very few weeks' feeding on these low-ash rations was found to cause weakened tendinous attachments, spreading feet, "cocked ankles" and lameness.

The administration of a laxative was found to cause a very rapid increase in weight, and decrease of urine, and where a laxative had not been administered a rapid gain in weight and decrease in urine came to be recognized as indications of approaching digestive disturbance.

The table on page 8 sets forth the nitrogen and mineral balances determined in this experiment, the upper line of balances from each pig (Period I) being derived from the preliminary period, in which no phosphatic supplements were fed, while the lower lines of balances (Periods II and III) were from the periods in which the phosphorus compounds were administered.

The pigs in this experiment weighed about 80-90 pounds each at the beginning of the work. While on experiment they gained in weight about a pound per head daily on an intake of four pounds of feed per 100 pounds live weight, a rate of increase somewhat lower than would be expected under normal practical conditions of treatment.

BALANCE EXPERIMENTS WITH GROWING SWINE, COMPARING PHOSPHORUS COMPOUNDS

Grams per Day—Experiment I; 10-day Periods

Pig and period No.	Live weight Initial / Final Lbs.	Average daily ration	N Food	N Urine	N Feces	N Balance	S Food	S Urine	S Feces	S Balance	P Food	P Urine	P Feces	P Balance	Ca Food	Ca Urine	Ca Feces	Ca Balance	Mg Food	Mg Urine	Mg Feces	Mg Balance	K Food	K Urine	K Feces	K Balance
1 Period I	81.00 / 87.75	Hominy	1310.13				26.421				2.255				0.671				0.277				0.287			0.719
		Blood albumen	40.25				17.094				1.169				0.026				0.177				0.068			0.164
		Wheat gluten	40.25				1.662				0.203				0.309				0.142				0.121			0.274
		Senna	2.40			+7.665				+0.883				+0.336				−0.042				+0.098				+0.281
1 Period II	88.25 / 99.25	Hominy	1314.71				26.720				2.272				1.287				0.251				0.296			1.114
		Blood albumen	41.32				17.078				1.248				0.435				0.001				0.045			0.185
		Wheat gluten	41.32				1.175				0.153				0.205				0.074				0.087			0.238
		Senna	1.00			+8.467				+0.871				+0.647				+0.176				+0.164				+0.691
		Phosphates (P)	0.613																							
1 Period III	100.75 / 109.00	Hominy	1245.63				25.263				2.149				1.210				0.206				0.273			1.042
		Blood albumen	39.03				16.084				1.138				0.464				0.005				0.059			0.310
		Wheat gluten	39.03				1.150				0.164				0.235				0.070				0.102			0.262
		Phosphates (P)	0.573			+8.029				+0.847				+0.511				+0.131				+0.112				+0.470
2 Period I	84.50 / 92.25	Hominy	1383.30				27.621				2.365				0.706				0.286				0.302			0.754
		Blood albumen	41.44				18.405				1.337				0.021				0.077				0.078			0.132
		Wheat gluten	41.44				1.506				0.198				0.268				0.160				0.115			0.226
		Senna	2.40			+7.710				+0.830				+0.417				+0.049				+0.109				+0.396
2 Period II	92.75 / 102.50	Hominy	1389.38				29.292				2.399				1.332				0.285				0.343			0.814
		Blood albumen	43.40				18.825				1.370				0.341				0.004				0.071			0.298
		Wheat gluten	43.40				1.153				0.148				0.217				0.089				0.123			0.234
		Senna	2.00			+9.314				+0.881				+0.774				+0.192				+0.149				+0.282
		Nucleic acid (P)	0.619																							
2 Period III	104.25 / 112.25	Hominy	1288.13				27.153				2.223				1.232				0.216				0.307			0.739
		Blood albumen	40.39				17.778				1.185				0.562				0.009				0.125			0.389
		Wheat gluten	40.39				1.149				0.195				0.225				0.073				0.170			0.212
		Nucleic acid (P)	0.574			+8.226				+0.843				+0.445				+0.134				+0.012				+0.138
3 Period I	89.50 / 96.50	Hominy	1451.70				28.773				2.471				0.738				0.303				0.319			0.788
		Blood albumen	42.65				18.816				1.386				0.022				0.154				0.090			0.178
		Wheat gluten	42.70				2.083				0.227				0.262				0.110				0.125			0.194
		Senna	2.40			+7.874				+0.858				+0.454				+0.039				+0.104				+0.416
3 Period II	97.25 / 109.25	Hominy	1435.19				29.057				2.478				1.384				0.320				0.326			1.063
		Blood albumen	44.50				18.237				1.327				0.630				0.006				0.061			0.173
		Wheat gluten	44.50				1.359				0.167				0.175				0.068				0.122			0.197
		Senna	3.00			+9.461				+0.984				+0.579				+0.246				+0.143				+0.693
		Hypophosphites (P)	0.648																							
4 Period I	90.25 / 99.75	Hominy	1501.13				29.563				2.545				0.760				0.287				0.323			0.809
		Wheat gluten	43.44				19.245				1.360				0.019				0.162				0.096			0.131
		Blood albumen	43.44				2.137				0.229				0.344				0.184				0.125			0.493
		Senna	1.90			+8.181				+0.956				+0.397				−0.059				+0.102				+0.185
4 Period II	100.38 / 107.00	Hominy	1276.66				25.974				2.208				1.265				0.295				0.575			1.138
		Blood albumen	40.14				18.094				1.349				0.225				0.008				0.119			0.116
		Wheat gluten	40.14				1.765				0.220				0.368				0.140				0.236			0.330
		Senna	2.00			+6.115				+0.639				+0.672				+0.147				+0.220				+0.692
		Glycerophosphates	0.609																							

DISCUSSION OF RESULTS FROM EXPERIMENT I

That phosphorus in each form (phosphates, glycerophosphates, nucleic acid and hypophosphites) was absorbed and retained is unquestionably true, even the hypophosphites increasing the urinary phosphorus and the phosphorus retention. It is not considered, however, that retention of phosphorus from hypophosphites for 10 days constitutes entirely conclusive evidence that it was actually utilized. In comparison with requirements of calcium for normal growth, these pigs all suffered from a deficient intake of this element. Conditions were not considered favorable for a close comparison of the nutritive values of the phosphorus compounds involved. No marked differences were noted in the response of the animals to these preparations.

EXPERIMENT II

Experiment II, conducted in November and December 1908, consisted of a feeding and carcass analysis experiment, covering 56 days, and involving the use of 30 pigs—five individuals in each of six lots. The pigs were eight months old at the beginning of the experiment, and in good stock condition. They were of mixed breeding. The basal ration was composed of pearl hominy, blood albumen, wheat gluten and corn bran. Salt was allowed *ad libitum*. Corn meal and chalk were introduced into the diet at certain times, for corrective purposes, the corn meal proving efficient to restore normal conditions, but the chalk apparently not being of value for the intended purpose. The phosphorus compounds compared were the same as in Experiment I. After a two weeks' preliminary feeding on the low-phosphorus basal ration the several lots were given rations as follows:

Lot 1, basal ration plus hypophosphites
Lot 2, basal ration plus hypophosphites and nucleic acid
Lot 3, basal ration plus glycerophosphates
Lot 4, basal ration plus phosphates
Lot 5, basal ration alone
Lot 6, check lot, killed at beginning of experiment

The average initial weight of the pigs was 91.87 pounds; the average final weight, 56 days later, was 151.47 pounds, the daily gain being 1.06 pounds per head—all lots taken together.

The pigs in Lots 1 and 2 suffered from great weakness and lameness; they were also more or less subject to indigestion. The legs were weak, especially the hind ones, which trembled, and bowed out, and the feet were set far under the body. The fore feet were also sore. The muscular control was poor, and difficulty was

experienced in stepping up 6 inches onto the feeding platform. These pigs lay down most of the time, and if disturbed would at once lie down again. They ate well, but moved slowly, carefully and without spirit. Lot 5, which received no phosphorus supplement, behaved much as did Lots 1 and 2, but the abnormal tendencies were less pronounced. The pigs of Lot 3, receiving glycerophosphates, were entirely normal; they ran and played in the best of spirits. The pigs of Lot 4, receiving phosphates, also remained in good condition, though they were less active than the pigs receiving glycerophosphates. The above-mentioned pathological conditions are considered to have been due largely to the low calcium and low phosphorus content of the diet. We are unable satisfactorily to explain the freedom from lameness of the pigs which received glycerophosphates.

Considerable difficulty was experienced in the management of the feeding, Lots 1, 2 and 4 having capricious appetites and requiring frequent reduction in the amount of food given, and in the amount of the phosphorus supplements. These reductions it was not possible to make up by subsequent increase. On these accounts the food consumption could not be maintained uniform in all lots, a fact which resulted in certain advantage to the pigs receiving glycerophosphates. One pig in Lot 1 was thrown out of the experiment after 23 days' feeding because of inability to digest the food. Its live weight, 94 pounds, was so close to the average of the lot (91.95 pounds) that it was considered to have eaten a fifth of the food, and the amount thus computed was deducted from the total charged to the lot. The nutritional disorders in certain lots, as above noted, were successfully combatted by the feeding of limited amounts of corn, which in this relation appeared to possess marked curative value, perhaps due to its organic phosphorus compounds—perhaps to vitamines. The basal ration, by the way, was very poor in fats, but we were unsuccessful in efforts to feed corn oil added to these foods.

The experimental data included analyses of the foods, weights of foods and live animals, slaughter weights of parts and organs, and analyses of the hams, brains, livers, kidneys, femora, and tibiae; the data on composition of tissues in all cases representing composite samples from the 5 individuals in an experimental lot. The numerical data from this experiment are set forth in the following group of tables. For a discussion of these data see page 18.

EXPERIMENT II, TABLE I. FOOD CONSUMED AND GAIN IN LIVE WEIGHT

Lots and rations	Av. initial live weight	Av. final live weight	Av. daily feed per head	Av. daily gain per head	Feed per cwt. gain	Organic nutrients per head and day			
						Protein	Carbohydrates	Crude fiber	Ether extract
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Grams	Grams	Grams	Grams
1 Basal ration; hypophosphites	91.4	151.4	3.86	1.07	360.67	214.5	129.3	12.6	19.6
2 Basal ration; hypophosphites; nucleic acid	92.3	150.2	3.91	1.04	378.83	219.2	130.6	12.9	20.3
3 Basal ration; glycerophosphates	91.5	157.6	3.98	1.18	337.75	220.0	132.4	13.3	20.4
4 Basal ration; phosphates	91.8	155.1	3.95	1.13	348.92	219.1	138.1	13.0	20.5
5 Basal ration alone	91.9	143.0	3.63	.91	397.64	202.2	121.5	12.0	19.1

Length of experiment, 56 days.

EXPERIMENT II, TABLE II. TOTAL FOODS CONSUMED PER LOT OF FIVE PIGS

Lot No.	Hominy	Blood albumen	Wheat gluten	Corn bran	Corn	Calcium carbonate	Supplementary phosphorus
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Grams (P)
1	679.1	25 1	25.1	5.8	125.4	3.552	212.531
2	850.5	31.8	31.8	7.11	166.0	4.412	245.385
3	864.2	32.2	32.2	7.3	166.3	4.557	299.281
4	859.0	32.1	32.1	7.2	167.3	4.458	247.322
5	788.5	29.6	29.6	6.5	158.2	4.083	

Length of experiment, 56 days.

EXPERIMENT II, TABLE III. BALANCE BETWEEN BASIC AND ACID MINERALS IN AVERAGE DAILY RATION

Lots	Rations	Daily mineral consumption per pig—Grams							C. C. normal solution		
		Potassium	Sodium	Calcium	Magnesium	Phosphorus	Sulphur	Chlorine	Total acid	Total base	Excess acid
1	Basal ration; hypophosphites. ...	2.591	.907	3.030	.590	2.523	2.830	1.384	378 35	320.80	73.26
2	Basal ration; hypophosphites; nucleic acid.....	2.561	.846	3.016	.626	2.500	2.867	1.397	379.55	303.94	75.61
3	Basal ration; glycerophosphates....	3.030	1.354	3.166	1.120	2.743	2.903	1.420	398 13	385.99	12.14
4	Basal ration; phosphates	2.843	1.441	3.062	.625	2.519	2.893	1.412	382.43	339.14	43.29
5	Low phosphorus basal ration...	2.095	.532	2.776	.556	1.525	2.669	1.302	301.62	260.69	40.93

EXPERIMENT II, TABLE IV. SLAUGHTER RECORDS—AVERAGE WEIGHTS OF PARTS—Pounds

Lots	Phosphorus compounds fed	Live weight	Gross dressed weight	Brain	Heart	Liver	Lungs	Kidneys	Spleen	Leaf lard	Thickness of back fat Inches
1	Hypophosphites	151.4	116.0	.200	.465	2.56	.757	.464	.196	5.90	1.38
2	Hypophosphites; nucleic acid.....	150.2	114.6	.222	.450	2.37	.803	.468	.178	5.21	1.18
3	Glycerophosphates	157.6	120.6	.213	.481	2.12	.805	.387	.162	4.52	1.13
4	Phosphates.....	155.1	107.1	.211	.472	2.47	.799	.463	.181	4.88	1.33
5	No phosphorus added to basal ration.....	143.0	99.3	.207	.429	2.15	.737	.450	.149	4.41	1.18
6	Check lot, killed at beginning of experiment...	92.5	66.4	.208	.331	1.85	.723	.331	.094	1.825	.59

EXPERIMENT II, TABLE V. AVERAGE WEIGHT AND COMPONENTS OF HAMS

Lots	Phosphorus compounds fed	Trimmed ham Lbs.	Skin of ham Lbs.	Bones in ham Lbs.	Fat in ham Lbs.	Muscle in ham; total Lbs.	Muscle, semimembranosus Grams	Muscle, semitendinosus Grams	Muscle, gastrocnemius Grams	Water in flesh Lbs.	Fat in flesh Lbs.	Protein in flesh Lbs.	Ash in flesh Lbs.	Phosphorus in flesh Grams
1	Hypophosphites.....	9.61	.47	.78	3.45	4.79	370.3	151.0	213.0	3.999	2.961	1.216	.0638	5.244
2	Hypophosphites; nucleic acid..	10.15	.47	.89	3.46	5.20	400.0	170.5	237.9	4.312	2.994	1.334	.0674	5.684
3	Glycerophosphates	10.81	.52	1.00	3.20	5.96	462.0	216.4	254.7	4.881	2.760	1.462	.0762	6.486
4	Phosphates	10.21	.46	.86	3.38	5.37	403.5	192.3	227.9	4.288	3.043	1.350	.0679	5.915
5	Low phosphorus basal ration..	9.97	.47	.79	3 29	5.29	393.3	172.4	230.2	4.379	2.754	1.334	.0694	5.924
6	Check lot; not fed....	6.625	.279	.80	1.502	3.34	282.3	115.0	160.6	2.723	1.272	.759	.0424	3.552

EXPERIMENT II, TABLE VI. COMPOSITION OF SKINNED HAMS—Percent

Lots	Phosphorus compounds fed	Water in flesh	Fat in flesh	Protein in flesh	Ash in flesh	Phosphorus in flesh	Bones in ham
1	Hypophosphites	44.336	32.828	13.481	.7073	.00140	8.648
2	Hypophosphites; nucleic acid	44.929	31.196	13.900	.7023	.00144	9.273
3	Glycerophosphates	47.951	27.114	14.363	.7486	.00155	9.824
4	Phosphates	44.625	31.669	14.049	.7066	.00149	8.950
5	Low phosphorus basal ration	46.953	29.529	14.303	.7441	.00153	8.471
6	Check lot; not fed	48.656	22.729	13.562	.7578	.00163	14.295

EXPERIMENT II, TABLE VII. PERCENT GAIN IN PARTS CORRESPONDING TO ONE PERCENT GAIN IN LIVE WEIGHT

Lots	Phosphorus compounds fed	Gross dressed weight	Brain	Heart	Liver	Lungs	Kidneys	Spleen	Leaf fat	Thickness of back fat	Weight of bones in ham	Fat in ham	Muscle in ham
1	Hypophosphites	1.44	—.044	.643	.608	.090	.639	1.54	3.45	2.05	—.020	2.03	.689
2	Hypophosphites; nucleic acid	1.14	.107	.580	.447	.182	.666	1.42	2.94	1.59	.180	2.08	.909
3	Glycerophosphates	1.41	.047	.645	.219	.172	.249	1.03	2.07	1.31	.368	1.61	1.109
4	Phosphates	1.14	.035	.635	.495	.164	.596	1.37	2.43	1.81	.129	1.84	.893
5	Low phosphorus basal ration	.91	.000	.547	.302	.045	.662	1.08	2.56	1.80	—.023	2.17	1.066

EXPERIMENT II, TABLE VIII. DATA CONCERNING DEVELOPMENT OF BONES

Femora

Lots	Phosphorus compounds fed	Volume C. C.	Breaking strength Lbs.	Length Cm.	Longer diameter Cm.	Shorter diameter Cm.	Gain in breaking strength Percent	Ash per c. c. volume Grams	Ash Percent	Calcium in ash Percent	Magnesium in ash Percent	Phosphorus in ash Percent
1	Hypophosphites.....	89.7	208	15.25	1.77	1.64	—37.0	.209	18.72	36.59	.70	17.18
2	Hypophosphites; nucleic acid..	102.1	290	15.90	1.84	1.70	—11.6	.227	23.14	36.91	.71	17.26
3	Glycerophosphates	108.5	402	16.50	2.03	1.77	28.7	.309	33.54	37.01	.88	17.69
4	Phosphates....	100.8	365	16.10	1.86	1.64	11.3	.275	27.71	36.91	.82	17.50
5	Low phosphorus basal ration..	92.2	241	15.60	1.87	1.70	—26.5	.226	20.82	36.84	.64	17.53
6	Check lot; not fed.....	77.4	328	14.70	1.75	1.59	.....	.285	22.05	36.95	.80	17.78

EXPERIMENT II, TABLE IX. DATA CONCERNING DEVELOPMENT OF BONES

Tibiae

Lots	Phosphorus compounds fed	Volume C. C.	Breaking strength Lbs.	Length Cm.	Longer diameter Cm.	Shorter diameter Cm.	Gain in breaking strength Percent	Ash per c. c. volume Grams	Ash Percent	Calcium in ash Percent	Magnesium in ash Percent	Phosphorus in ash Percent
1	Hypophosphites.....	55.4	269	13.9	1.77	1.21	—39.1	.255	14.10	37.41	.59	17.06
2	Hypophosphites; nucleic acid..	61.2	325	14.4	1.81	1 25	—26.4	.285	17.43	37.51	.58	17.22
3	Glycerophosphates.....	67.7	514	15.0+	1.95	1.37	16.4	.363	24.54	37.27	.66	17.53
4	Phosphates.....	62.6	423	15.0—	1.79	1.26	—4.1	.339	21.25	37.55	.70	17.32
5	Low phosphorus basal ration..	55.2	311	14.2	1.78	1.26	—29.5	.278	15.33	37.75	.66	17.28
6	Check lot; not fed.....	47.7	441	13.5	1.72	1.21	.....	.346	16.53	37.70	.70	17.68

EXPERIMENT II, TABLE X. BREAKING STRENGTH OF BONES—Pounds

Lot No.	Phosphorus compounds fed	Pig No.	Femur	Tibia
I	Hypophosphites	1	210	345
		2	200	215
		3	195	245
		4	225	270
		Average..	207.5	269
II	Hypophosphites; nucleic acid	1	315	280
		2	225	310
		3	175	325
		4	355	375
		5	380	335
		Average..	290	325
III	Glycerophosphates	1	295	505
		2	325	395
		3	420	450
		4	500	590
		5	470	600
		Average..	402	514
IV	Phosphates	1	390	510
		2	300	410
		3	520	520
		4	350	385
		5	265	290
		Average..	365	423
V	Low phosphorus basal ration	1	300	385
		2	135	215
		3	270	340
		4	275	350
		5	225	265
		Average..	241	311
VI	Check lot; not fed	1	295	350
		2	410	570
		3	375	470
		4	310	375
		5	250	440
		Average..	328	441

EXPERIMENT II, TABLE XI. COMPOSITION OF ORGANS AND TISSUES—Percent

Tissue	Lot	Treatment	Water	Ether extract	Protein (Nx6.25)	Ash	Phosphorus	Inorganic phosphorus	Water in fat-free material	Fat in water-free material	Proportion ash to protein	Phosphorus in ash	Relation inorganic to total phosphorus	Organic phosphorus
Muscle of ham	1	Hypophosphites	72.92	3.97	22.38	1.142	.2196	.1250	75.93	14.66	5.10	19.23	56.92	.0946
	2	Hypophosphites; nucleic acid	71.98	5.34	22.21	1.121	.2096	.1220	76.04	19.06	5.05	18.70	58.21	.0876
	3	Glycerophosphates	73.16	3.86	22.08	1.145	.2163	.1160	77.71	14.38	5.19	18.89	53.63	.1003
	4	Phosphates	71.21	5.21	22.16	1.128	.2190	.1390	75.12	18.10	5.09	19.41	63.47	.0900
	5	Low phosphorus	72.09	4.75	22.14	1.146	.2171	.1250	75.69	17.05	5.18	18.94	57.58	.0921
	6	Check	73.81	3.69	20.44	1.137	.2180	.0820	76.67	14.11	5.56	19.17	37.61	.1360
Fat of ham	1	Hypophosphites	14.67	80.31	4.18	.264	.0440	.....	74.50	94.12	6.32	16.67	.....	.....
	2	Hypophosphites; nucleic acid	16.45	78.51	5.19	.262	.0470	.....	76.55	93.97	5.05	17.94	....	.....
	3	Glycerophosphates	16.27	79.07	4.56	.249	.0438	.....	77.74	94.43	5.46	17.59	.....	.....
	4	Phosphates	13.74	81.75	4.74	.215	.0379	.....	75.29	94.77	4.54	17.63	.....	.....
	5	Low phosphorus	17.17	76.07	4.94	.266	.0479	.....	71.75	91.84	5.38	18.12	.....	.....
	6	Check	17.27	76.51	5.06	.295	.0365	.....	72.92	92.33	5.83	12.37	.....	.....
Brain	1	Hypophosphites	77.48	7.87	10.91	1.390	.3196	.0566	84.10	34.95	12.74	22.99	17.71	.2630
	2	Hypophosphites; nucleic acid	77.66	8.08	10.99	1.390	.3082	.0578	84.70	36.50	12.65	22.17	18.75	.2504
	3	Glycerophosphates	77.55	7.96	10 95	1.450	.3424	.0482	84.26	35 46	13.24	23.61	14.08	.2942
	4	Phosphates	77.93	8.05	10.88	1.410	.3132	.0634	84.75	36.47	12.96	22.21	20.24	.2498
	5	Low phosphorus	77.66	7.68	11.00	1.420	.3110	.0549	84.12	34.38	12.91	21.90	17.65	.2561
	6	Check	78.47	8.19	10.63	1.370	.2950	.....	85.48	38.06	12.89	21.53	.....	.....
Liver	1	Hypophosphites	70.97	2.87	20.19	1.470	.3413	.0818	73.07	9.89	7.28	23.22	23.96	.2595
	2	Hypophosphites; nucleic acid	71.33	2.84	20.08	1.440	.3485	.0821	73.41	9.91	7.17	24.20	23.56	.2664
	3	Glycerophosphates	70.45	2.78	21.22	1.450	.3497	.0826	72.46	9.41	7.07	23.31	23.62	.2671
	4	Phosphates	70.23	2.57	21.68	1.490	.3642	.0911	72.08	8.63	6.87	24.44	25.01	.2731
	5	Low phosphorus	71.28	2.73	20.81	1.510	.3388	.0924	73.28	9 51	7.26	22.44	27.27	.2464
	6	Check	70.89	1.80	18.63	1.400	.3040	.....	72.19	6.18	7.51	21.71	.....	.....
Kidney	1	Hypophosphites	79.60	3.00	15.38	1.180	.2482	.0590	82.06	14.71	13 03	21.03	23.77	.1892
	2	Hypophosphites; nucleic acid	80.08	3.15	15.31	1.190	.2466	.0624	82.68	15.81	12.87	20.72	25.30	.1842
	3	Glycerophosphates	79.41	3.56	16.06	1.220	.2628	.0701	82.34	17.29	13.16	21.54	26.67	.1927
	4	Phosphates	80.27	2.86	14.69	1.160	.2423	.0543	82.63	14.50	12.66	20.89	22.41	.1880
	5	Low phosphorus	80.24	2.86	14.69	1.150	.2415	.0476	82.60	14.47	12.77	21.00	19.71	.1939
	6	Check	80.75	2.07	12.94	1.120	.2363	.....	82.46	10.75	8.66	21.10	.....	.....

DISCUSSION OF RESULTS FROM EXPERIMENT II

In looking through the foregoing tables one must be struck with the very considerable number of concordant observations indicating specific effects and superior nutritive values of the glycerophosphates as distinct from all other phosphorus compounds administered. A still more prominent result (already mentioned) was the behavior of the pigs. The superior activity and spirit of those receiving glycerophosphates was remarked upon by all observers. It is true that these pigs had received a little more phosphorus than the others. This was due to the irregular food consumption of the pigs receiving the other compounds, which resulted in disturbance of the plans of the investigation.

The main evidence of superiority of glycerophosphates were as related to the development and composition of bone and muscle. To enumerate a few of these differences—the pigs which received glycerophosphates made the greatest gain in weight per unit of food consumed (Table I, p. 11); the least development of leaf fat and back fat (Table IV, p. 12); the greatest development of bone and muscle in the ham, and the least development of liver, kidneys, spleen, leaf fat, back fat and fat in the ham—all as related to the gain in live weight (Table VII, p. 14); the maximum amount of moisture, protein, ash and phosphorus in the flesh of the hams, and the minimum amount of fat in the same (Table VI, p. 14); the largest, strongest and densest bones (Tables IX and X, pp. 15 and 16); the most water in the fat-free muscle, and the lowest fat in the water-free muscle; also, in the brain, the highest total and lowest inorganic phosphorus, the highest proportion of ash to protein, of phosphorus to ash and of organic to inorganic phosphorus (Table XI, p. 17).

There is also considerable evidence, similar in character, inclining one to conclude that, among the several compounds compared, the hypophosphites possessed the lowest nutritive value.

In connection with these many concordant data the important consideration is as to whether the facts are primarily due to actual fundamental nutritive differences in the phosphorus compounds fed or whether they are secondary results of more superficial differences in the reaction of the subject to the treatment. There is no question as to the natural inference from the data recorded. We shall reserve further comment for the discussion of later evidence.

EXPERIMENT III

Experiment III, conducted during November and December, 1909, and January, 1910, was similar to Experiment II. The feeding covered a period of 70 days, and the experiment involved 35 pigs of mixed Berkshire and Poland China breeding, in 7 lots of 5 each. The basal ration consisted of pearl hominy, wheat gluten, blood albumen and corn bran. Salt was allowed *ad libitum*. To this basal ration were added, at various times during the experiment, chalk, soda, sugar and corn meal, in efforts to relieve difficulties in the feeding. Without some corn it seemed to be impossible to keep the pigs in condition for experimentation. The necessity of feeding the corn was much regretted, as this increased the organic phosphorus, and tended to put all experimental lots on the same basis. The phosphorus compounds compared were the same mixtures used in Experiments I and II. In addition commercial phytin was fed to Lot 5. The several lots received rations as follows:

Lot 1, basal ration plus hypophosphites
Lot 2, basal ration plus nucleic acid
Lot 3, basal ration plus glycerophosphates
Lot 4, basal ration plus phosphates
Lot 5, basal ration plus phytin
Lot 6, basal ration alone
Lot 7, check lot, killed at beginning of experiment

Difficulties in the feeding were encountered in all lots except the one receiving glycerophosphates, and the one which received no phosphorus supplement. The pigs receiving glycerophosphates were much the most spirited and active of any in the series. Hypophosphites and nucleic acid, when fed in amounts furnishing 2 grams of phosphorus daily to each lot of 5 pigs caused nausea, vomiting and indigestion. Phytin appeared to cause indigestion, but not pronounced nausea. As a whole the pigs in this series were much less tolerant of the phosphorus compounds fed (other than glycerophosphates) than those in Experiment II. In this experiment even the pigs receiving orthophosphates exhibited very limited tolerance for the mineral supplement. The numerical data from this experiment are set forth in the following group of tables. For a discussion of these results see page 28.

EXPERIMENT III, TABLE I. FOOD CONSUMED AND GAIN IN LIVE WEIGHT

Lot No.	Phosphorus compounds fed	Average initial live weight Lbs.	Average final live weight Lbs.	Average daily feed per head Lbs.	Average daily gain per head Lbs.	Feed per Cwt. gain Lbs.	Organic nutrients per head and day				
							Protein Grams	Carbohydrates Grams	Crude fibre Grams	Ether extract Grams	Total organic* nutrients Grams
1	Hypophosphites	114.20	171.97	3.595	.825	435.6	192.3	1198.1	12.4	22.7	1425.5
2	Nucleic acid	114.20	155.80	3.114	.594	524.0	166.2	1036.5	10.6	19.0	1232.3
3	Glycerophosphates	114.40	174.25	3.597	.855	420.7	192.0	1196.5	12.4	22.4	1423.3
4	Phosphates	114.30	168.47	3.556	.774	459.5	190.1	1184.1	12.3	22.4	1408.9
5	Phytin	114.20	159.60	3.338	.649	514.7	178.5	1112.1	11.5	20.8	1322.9
6	Low-phosphorus basal ration	114.30	168.25	3.564	.771	462.4	190.8	1188.5	12.4	22.5	1414.2

*Organic phosphorus supplements not included in this figure.

EXPERIMENT III, TABLE II. TOTAL FOODS CONSUMED PER LOT OF FIVE PIGS

Lot No.	Hominy Lbs.	Blood albumen Lbs.	Wheat gluten Lbs.	Corn bran Lbs.	Corn Lbs.	Calcium carbonate Lbs.	Sodium bi-carbonate Lbs.	Sugar Lbs.	Supplementary phosphorus Grams P
1	957.4	32.4	32.4	17.3	196.5	3.73	.16	17.34	154.481
2	841.3	28.3	28.3	15.6	154.1	3.72	.08	15.62	108.185
3	962.5	32.5	32.5	17.7	188.3	3.96	.15	17.70	156.726
4	948.1	32.1	32.1	17.2	192.1	3.75	.14	17.15	152.901
5	894.5	30.2	30.2	16.5	175.0	3.73	.14	16.50	128.855
6	951.1	32.2	32.2	17.4	192.9	3.79	.17	17.40	.....

Length of experiment 70 days.

EXPERIMENT III, TABLE III. BALANCE BETWEEN BASIC AND ACID MINERALS IN DAILY RATIONS

Lots	Phosphorus compounds fed	Daily mineral consumption per pig—Grams							Cubic centimeters normal solution		
		Potassium	Sodium	Calcium	Magnesium	Phosphorus	Sulphur	Chlorine	Total acid	Total base	Excess acid
1	Hypophosphites	1.5164	0.7412	2.0436	0.5466	1.8485	3.8863	1.0114	390.23	217.70	172.53
2	Nucleic acid	1.1339	0.5052	2.0201	0.4523	1.4890	3.3660	0.8748	333.61	188.78	144.85
3	Glycerophosphates	1.4547	0.7163	2.4989	0.6246	1.8344	3.8828	1.0087	389.02	244.15	144.87
4	Phosphates	1.5800	0.9649	2.1015	0.5435	1.8226	3.8418	0.9997	385.45	231.65	153.80
5	Phytin	1.2320	0.5407	2.2434	0.5086	1.6572	3.6091	0.9388	358.55	208.58	149.97
6	Low phosphorus basal ration	1.3179	0.5788	2.0665	0.5329	1.3913	3.8552	1.0033	358.56	205.59	152.97

EXPERIMENT III, TABLE IV. SLAUGHTER RECORDS

Average Weights of Parts

Lots	Phosphorus compounds fed	Initial live weight	Final live weight	Gross dressed weight	Brain	Heart	Liver	Lungs	Kidneys	Spleen	Leaf fat	Thickness of back fat
		Lbs.	Lbs.	Lbs.	Grams	Oz.	Lbs.	Oz.	Oz.	Oz.	Lbs.	Inches
1	Hypophosphites	114.20	171.97	138.7	121.7	7.89	2.27	13.45	8.24	3.34	6.45	1.30
2	Nucleic acid	114.20	155.80	119.2	118.1	7.31	2.18	13.00	7.94	2.98	4.78	1.10
3	Glycerophosphates	114.40	174.25	139.1	124.1	8.51	2.34	15.00	7.84	3.55	5.72	1.29
4	Phosphates	114.30	168.47	131.1	120.1	7.97	2.42	14.38	7.79	3.20	5.95	1.23
5	Phytin	114.20	159.60	124.1	118.4	7.31	2.73	15.51	6.68	2.65	5.56	1.16
6	Low phosphorus basal ration	114.30	168.25	133.7	115.0	8.15	2.26	15.12	8.19	3.10	5.33	1.11
7	Check lot; not fed	114.45	.....	83.6	107.8	6.95	2.28	14.17	6.42	2.19	2.12	.75

EXPERIMENT III, TABLE V. AVERAGE WEIGHT AND COMPONENTS OF HAMS

No.	Phosphorus compounds fed	Total ham, skinned	Skin of ham	Bones in ham	Fat in ham	Muscle in ham	Muscle, semimembranosus	Water in flesh	Fat in flesh	Protein in flesh	Ash in flesh	Phosphorus in flesh
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Grams	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	Hypophosphites.....	11.57	0.61	1.11	3.65	6.78	501	5.539	3.157	1.686	.0791	.0168
2	Nucleic acid..... ..	10.21	0.50	1.05	3.29	5.86	435	4.836	2.797	1.455	.0691	.0146
3	Glycerophosphates	12.06	0.55	1.14	3.59	7.29	563	5.865	3.101	1.860	.0939	.0199
4	Phosphates.....	11.33	0.50	1.06	3.78	6.45	481	5.351	3.220	1.623	.0745	.0161
5	Phytin..... . .	10.98	0.48	1.02	3.72	6.19	447	5.186	3.144	1.559	.0735	.0154
6	Low phosphorus basal ration..	11.54	0.45	1.11	3.62	6.78	521	5 544	3.132	1.676	.0777	.0166
7	Check lot; not fed	7.81	0.43	0.86	1.83	5.08	369	4.121	1.573	1.197	.0592	.0115

EXPERIMENT III, TABLE VI. PERCENTAGE COMPOSITION OF SKINNED HAMS

Lot No.	Phosphorus compounds fed	Water in flesh	Fat in flesh	Protein in flesh	Ash in flesh	Phosphorus in flesh	Bones in ham
1	Hypophosphites	47.9	27.3	14.60	.684	.145	9.59
2	Nucleic acid	47.4	27.4	14.25	.677	.143	10.28
3	Glycerophosphates	48.6	25.7	15.42	.779	.165	9.45
4	Phosphates	47.2	28.4	14.32	.658	.142	9.36
5	Phytin	47.2	28.6	14.20	.669	.140	9.29
6	Low-phosphorus basal ration	48.0	27.1	14.52	.673	.144	9.62
7	Check lot; not fed	52.8	20.1	15.33	.758	.147	11.01

EXPERIMENT III, TABLE VII. PERCENT GAIN OF HOGS AND PARTS CORRESPONDING TO ONE PERCENT GAIN IN LIVE WEIGHT

Lot No.	Phosphorus compounds fed	Gross dressed weight	Brain	Heart	Leaf fat	Thickness of back fat	Bones in ham	Fat in ham	Muscle in ham	Muscle, semimembranosus
1	Hypophosphites	1.30	.25	.27	4.04	1.45	.58	1.97	1.16	.71
2	Nucleic acid	1.17	.26	.14	3.45	1.28	.61	2.19	1.02	.49
3	Glycerophosphates	1.27	.29	.43	3.24	1.37	.62	1.84	1.35	1.00
4	Phosphates	1.20	.24	.31	3.81	1.35	.49	2.25	1.08	.64
5	Phytin	1.22	.25	.13	4.08	1.37	.47	2.60	1.13	.53
6	Low-phosphorus basal ration	1.27	.14	.37	3.21	1.02	.62	2.07	1.25	.87

EXPERIMENT III, TABLE VIII. DATA CONCERNING DEVELOPMENT OF BONES

Individual Measurements—Femur

Lot No.	Pig No.	Volume C. C.	Length Mm.	Longer transverse diam. Mm.	Shorter transverse diam. Mm.	Breaking strength Lbs.
I	1	95.90	15.6	2.03	1.23	350
	2	126.45	17.6	2.28	1.88	400
	3	117.60	16.2	2.12	1.91	305
	4	115.50	16.1	2.24	2.03	465
	5	132.20	17.5	2.36	1.86	330
Average.....		117.53	16.6	2.206	1.782	370
II	1	126.30	16.8	2.41	1.91	280
	2	106.25	15.8	2.19	1.32	425
	3	106.40	16.8	2.12	1.82	250
	4	134.00	17.1	2.32	1.91	450
	5	125.55	17.0	2.37	1.87	490
Average. . . .		119.70	16.7	2.282	1.766	379
III	1	102.60	15.6	2.17	1.75	315
	2	131.70	18.7	2.25	1.83	355
	3	141.50	17.1	2.20	2.04	315
	4	136.65	17.1	2.33	2.05	405
	5	130.25	17.6	2.42	1.90	380
Average.....		128.54	17.22	2.274	1.914	354
IV	1	88.00	15.3	2.01	1.63	395
	2	127.60	18.1	2.18	1.98	285
	3	129.45	18.0	2.23	1.94	375
	4	120.45	16.3	2.21	1.90	435
	5	113.65	16.4	2.13	1.79	280
Average.....		115.83	16.82	2.152	1.848	354
V	1	132.00	17.8	2.24	2.00	460
	2	99.70	15.2	2.22	1.92	290
	3	135.45	17.5	2.25	1.92	330
	4	115.35	15.8	2.31	1.97	435
	5	111.40	15.2	2.27	2.02	350
Average.....		118.78	16.3	2.258	1.966	373
VI	1	121.20	16.3	2.26	1.97	445
	2	117.40	17.7	2.15	1.94	295
	3	147.90	17.6	2.22	2.04	385
	4	113.60	15.8	2.23	1.91	190
	5	129.60	17.2	2.27	1.83	550
Average.....		125.94	16.92	2.226	1.938	373
VII	1	85.25	14.8	2.13	1.73	425
	2	101.20	16.5	2.02	1.84	415
	3	98.55	16.3	2.03	1.78	475
	4	83.25	14.2	1.88	1.76	375
	5	79.20	14.3	1.97	1.56	340
Average.....		89.49	15.22	2.006	1.734	406

EXPERIMENT III, TABLE IX. DATA CONCERNING DEVELOPMENT OF BONES

Individual Measurements—Tibia

Lot No.	Pig No.	Volume C. C.	Length Mm.	Longer transverse diam. Mm.	Shorter transverse diam. Mm.	Breaking strength Lbs.
I	1	57.45	14.3	1.96	1.32	290
	2	73.30	16.1	2.13	1.38	410
	3	71.80	15.3	2.04	1.41	350
	4	67.90	15.0	2.07	1.43	460
	5	82.00	16.1	2.15	1.48	425
Average.		70.49	15.36	2.07	1.404	387
II	1	71.20	15.3	2.09	1.39	310
	2	64.55	14.7	1.97	1.44	390
	3	64.60	15.5	1.99	1.36	340
	4	81.60	16.0	2.06	1.48	360
	5	73.60	16.0	2.15	1.36	370
Average.....		71.11	15.5	2.05	1.41	354
III	1	59.50	14.4	2.02	1.36	405
	2	76.00	17 5	1.98	1.39	385
	3	86.40	16.2	2.12	1.47	360
	4	80.80	15.8	2.26	1.48	365
	5	79.70	16.4	2.11	1.41	525
Average.....		76.48	16.1	2.10	1.42	408
IV	1	50.70	14:1	1.87	1.20	250
	2	75.20	16.6	2.09	1.52	370
	3	77.90	17.0	2.08	1.44	475
	4	76.70	15.6	2.14	1.49	310
	5	72.30	15.3	1.94	1.37	310
Average.....		70.56	15.7	2.02	1.40	343
V	1	75.80	16.5	2.15	1.45	425
	2	60.30	14 2	2.06	1.40	270
	3	82.20	16.5	2.07	1.48	395
	4	72.40	14.9	2.14	1.51	320
	5	61.45	14.0	2.27	1.33	315
Average.....		70.43	15.2	2.14	1.43	345
VI	1	69.50	15.2	2.10	1.40	355
	2	69.60	16.5	2.01	1.42	340
	3	88.50	16.5	2.04	1.46	365
	4	69.00	14.7	2.12	1.43	375
	5	77.60	15.8	2.10	1.36	480
Average.....		74.84	15.7	2.07	1.41	383
VII	1	50.20	13.4	1.94	1.33	270
	2	60.60	14.8	2.02	1.40	550
	3	57.10	14.8	1.93	1.38	560
	4	53.60	13.5	2.03	1.34	160
	5	47.45	13.3	1.77	1.27	340
Average.....		53.79	13.96	1.94	1.34	376

EXPERIMENT III, TABLE X. DATA CONCERNING DEVELOPMENT OF BONES

Femora

Lots	Phosphorus compounds fed	Volume C. C.	Ash Grams	Ash per c. c. volume Grams	Phosphorus Percent of ash	Calcium Percent of ash	Magnesium Percent of ash
1	Hypophosphites	117.5	31.57	0.269	17.57	38.61	.525
2	Nucleic acid	119.7	32.42	0.271	17.81	38.38	.590
3	Glycerophosphates	128.5	37.70	0.293	17.76	38.51	.638
4	Phosphates	115.8	32.42	0.280	17.59	38.46	.616
5	Phytin	118.8	31.48	0.265	17.52	38.61	.661
6	Low phosphorus basal ration	125.9	33.43	0.266	17.30	38.40	.558
7	Check lot; not fed	89.5	29.39	0.328	17.48	38.79	.578

EXPERIMENT III, TABLE XI. DATA CONCERNING DEVELOPMENT OF BONES

Tibiae

Lots	Phosphorus compounds fed	Volume C. C.	Ash Grams	Ash per c. c. volume Grams	Phosphorus Percent of ash	Calcium Percent of ash	Magnesium Percent of ash
1	Hypophosphites	70.5	23.22	0.329	17.38	38.61	.512
2	Nucleic acid	71.1	24.62	0.346	17.63	38.61	.547
3	Glycerophosphates	76.5	27.77	0.363	17.71	38.72	.617
4	Phosphates	70.6	24.50	0.347	17.44	38.54	.556
5	Phytin	70.4	23.66	0.336	17.40	38.98	.508
6	Low phosphorus basal ration	74.8	25.37	0.339	17.25	38.61	.613
7	Check lot; not fed	53.8	22.02	0.409	17.36	39.01	.567

EXPERIMENT III, TABLE XII. COMPOSITION OF TISSUES AND ORGANS—Percent

Part	Lot	Phosphorus compounds fed	Water	Ether extract	Protein (Nx6.25)	Ash	Total phosphorus	Inorganic phosphorus	Lecithin phosphorus	Water in fat-free material	Fat in water-free material	Proportion ash to protein	Phosphorus in ash	Proportion inorganic to total phosphorus	Total organic phosphorus
Muscle of ham	1	Hypophosphites	73.73	3.09	22.50	1.08	.230	.149	.0265	76.08	11.76	4.80	21.30	64.78	.081
	2	Nucleic acid	73.53	3.75	22.00	1.07	.227	.147	.0258	76.39	14.17	4.86	21.22	64.76	.080
	3	Glycerophosphates	72.72	3.62	23.13	Lost	.254	.147	.0268	75.45	13.27	....	.....	57.88	.107
	4	Phosphates	73.73	3.78	22.31	1.04	.226	.147	.0258	76.11	14.12	4.66	21.73	65.04	.079
	5	Phytin	73.19	4.09	22.00	1.06	.225	.135	.0229	76.31	15.25	4.82	21.23	60.00	.090
	6	Low-phosphorus	73.14	3.80	22.38	1.04	.225	.147	.0271	76.03	14.15	4.64	21.63	65.33	.078
	7	Check lot, not fed	74.62	3.21	21.83	1.09	.215	.136	.0274	77.09	12.64	4.99	19.72	63.26	.079
Fat of ham	1	Hypophosphites	14.78	80.74	4.46	.161	.033	....	...	76.74	94.74	3.61	19.88	.....	....
	2	Nucleic acid	16.02	78.32	5.06	.194	.039	....	....	73.89	93.26	3.83	20.01	.....	....
	3	Glycerophosphates	15.72	79.03	4.84	.199	.038	....	....	74.96	93.77	4.11	19.10	.....	....
	4	Phosphates	16.62	78.74	4.86	.196	.039	....	....	78.17	94.43	4.03	19.90	.....	....
	5	Phytin	17.64	77.72	5.29	.211	.041	....	....	79.17	94.37	3.99	19.43	.....	....
	6	Low-phosphorus	16.15	79.39	4.39	.184	.037	....	....	78.36	94.68	4.19	20.11	.....	....
	7	Check lot, not fed	18.02	77.06	4.81	.210	.035	...	....	78.55	94.00	4.37	16.67	.....	....
Brain	1	Hypophosphites	79.32	8.56	10.13	1.31	.317	.064	.217	86.74	41.39	12.93	24.20	20.19	.253
	2	Nucleic acid	79.53	8.66	10.00	1.29	.311	.059	.217	87.07	40.33	12.90	24.11	19.00	.252
	3	Glycerophosphates	79.30	8.74	10.00	1.31	.303	.061	.222	86.89	42.43	13.10	23.13	20.00	.242
	4	Phosphates	78.98	8.65	10.31	1.31	.323	.061	.222	86.45	41.15	12.71	24.66	18.73	.262
	5	Phytin	79.57	8.73	10.06	1.29	.311	.061	.218	87.18	42.73	12.82	24.11	19.55	.250
	6	Low-phosphorus	79.24	8.75	10.25	1.30	.312	.060	.222	86.84	42.15	12.68	24.00	19.30	.252
	7	Check lot, not fed	79.45	7.84	10.09	1.32	.305	.066	.224	86.21	38.15	13.08	23.08	21.75	.238
Liver	1	Hypophosphites	70.81	2.76	20.81	1.52	.372	.099	.1387	72.82	9.45	7.30	24.47	26.72	.273
	2	Nucleic acid	69.83	3.04	19.69	1.42	.345	.093	.1328	72.02	10.07	7.21	24.30	26.93	.252
	3	Glycerophosphates	70.04	2.75	21.06	1.47	.365	.094	.1292	72.02	9.18	6.85	24.83	25.75	.271
	4	Phosphates	71.27	3.04	20.69	1.44	.349	.092	.1413	73.50	10.58	6.96	24.24	26.30	.257
	5	Phytin	70.69	3.05	18.81	1.39	.332	.090	.1237	72.91	10.41	7.39	23.88	27.17	.242
	6	Low-phosphorus	70.44	3.10	21.00	1.49	.363	.092	.1443	72.69	10.49	7.09	24.36	25.34	.271
	7	Check lot, not fed	71.63	3.55	20.31	1.41	.351	.089	.1321	74.27	12.51	6.94	24.89	25.24	.262
Kidney	1	Hypophosphites	80.75	2.60	15.00	1.06	.233	.0710	.0744	82.91	13.51	7.07	21.98	30.47	.162
	2	Nucleic acid	79.25	3.43	15.69	1.07	.237	.0757	.0747	82.06	16.53	6.82	22.15	31.94	.161
	3	Glycerophosphates	79.42	3.84	15.44	1.08	.239	.0764	.0710	82.59	18.66	6.99	22.13	31.97	.161
	4	Phosphates	80.02	3.34	15.31	1.06	.234	.0714	.0742	82.78	16.72	6.92	22.08	30.51	.163
	5	Phytin	79.56	3.62	15.31	1 08	.245	.0723	.0707	82.55	17.71	7.05	22.68	29.51	.171
	6	Low-phosphorus	80.08	3.06	15.38	1.07	.247	.0697	.0719	82.61	15.36	6.96	23.08	28.22	.175
	7	Check lot, not fed	80.54	3.51	14.81	1.16	.238	.0674	.0729	83.47	18.04	7.83	20.52	28.32	.171

DISCUSSION OF RESULTS FROM EXPERIMENT III

As in the previous series the experimental data show that the pigs which received glycerophosphates were distinguished from all other lots in many ways such as to suggest a superior nutritive value of phosphorus in this condition; thus this lot exceeded all others in amount and economy of gain in live weight (Table I, p. 20). As related to the gain in live weight this lot rated first in increase in weight of brain, heart and muscle, (Table VII, p. 23). It also excelled all others in ash, volume and density of bones (Tables X and XI, p. 26); and the muscle in this lot contained the highest proportion of organic to total phosphorus (Table XII, p. 27).

The great difficulty experienced in the feeding, because of the limited and varying tolerance of the pigs for the phosphorus compounds fed (other than glycerophosphates) was the cause of much change and compromise in our plans. On this account the several lots compare, one with another, as to the many observations recorded in the several experiments, in somewhat different order.

EXPERIMENT IV

This experiment, conducted in November and December, 1910. and January, 1911, was similar in method to Experiments II and III, the feeding extending over a period of 70 days, and the experiment involving 45 pigs in 9 lots of 5 each. The subjects were selected from a lot of 57 pigs purchased at weaning time and reared together. This preliminary feeding extended over a period of 3½ months. The experimental lots were selected on the basis of live weight and previous gains in weight. The basal ration in Lots 1-5 consisted of pearl hominy, wheat gluten, blood albumen, corn bran and agar-agar, salt being allowed *ad libitum.* To this ration were added, during portions of the experiment, mangel wurzels and potassium citrate, for corrective purposes. Lots 6-8 received a similar ration, except that corn replaced the pearl hominy used in the food for Lots 1-5. The hypophosphites, nucleic acid and phosphates used were mostly of the same lots as those used in the earlier series, but the glycerophosphate mixture was soon exhausted, and was then replaced by calcium glycerophosphate alone. The phytin was in part a commercial product, and in part a preparation of the related compound from wheat bran.

The several lots received rations as follows:

Lot 1, hominy basal ration alone
Lot 2, hominy basal ration plus nucleic acid
Lot 3, hominy basal ration plus glycerophosphates
Lot 4, hominy basal ration plus phosphates

Lot 5, hominy basal ration plus phytin
Lot 6, corn basal ration plus precipitated bone flour
Lot 7, corn basal ration plus glycerophosphates
Lot 8, corn basal ration alone
Lot 9, check lot, killed at beginning of experiment

The pigs in this experiment exhibited, in general, the same symptoms as noted with regard to the previous series. The pigs which received nucleic acid and phytin, and those on the hominy basal ration alone, suffered from much weakness and soreness of the feet and legs. There was also considerable trouble with indigestion in these lots, as also in the phosphate lot, and the pigs receiving phytin showed some appearance of nausea. The glycerophosphate pigs, as usual, were entirely normal, and suffered only from the restricted food allowance necessitated by the unsatisfactory behavior of other lots. Lots 1, 2, 4 and 5 ate their own feces; Lots 3, 6, 7 and 8 showed no such tendency. In general the feeding was more successful than in previous experiments in that it was not found necessary to give any corn to the pigs on the hominy rations.

In Experiments II, III and IV it was necessary, because of digestive disturbance or lack of appetite, to reduce the amount of food allowed to one or more of the experimental lots on 51 dates. The pigs receiving glycerophosphates were not the occasion for any one of these food reductions, their immunity to nutritional disturbance being complete, and in marked contrast to the behavior of all other lots. Each of the other rations contributed in somewhat nearly the same proportion to the occasions for reduction of food allowance.

One litter of pigs involved in this work, though apparently normal at the beginning of the experiment, developed very peculiarly and abnormally, apparently as a litter characteristic, and without reference to the feeding. In varying degrees they took on a style of development similar to that of a Dachshund; the legs being very short, thick and much bowed; the growth, at the same time, was below the average. The individuals of this litter were scattered throughout several of the experimental lots. One of them, in the glycerophosphate lot was extreme in its deformity. Since the individuals in each lot were fed together, and since corresponding parts, though weighed separately were composited for analysis, it was impossible to eliminate the influence of this abnormal litter from the experiment.

The data from this experiment are set forth in the following group of tables. For a discussion of these results see page 36.

EXPERIMENT IV, TABLE I. FOOD CONSUMED AND GAIN IN LIVE WEIGHT

Lots	Rations	Av. initial weight	Av. final weight	Av. daily gain per head	Av. daily feed per head[1]	Organic nutrients per Cwt. gain[2]	Organic nutrients per head and day				
							Protein	Carbohydrates	Crude fiber	Ether extract	Total organic nutrients
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Grams	Grams	Grams	Grams	Grams
1	Hominy, albumen, gluten, etc., (basal ration)	109.75	161.20	.735	3.52	420.6	176.4	1191.2	11.36	23.26	1402
2	Basal ration; nucleic acid	109.40	166.85	.821	3.59	384.3	179.9[3]	1215.3	11.59	23.74	1431
3	Basal ration; glycerophosphates	109.30	169.15	.848	3.61	370.8	180.8	1221.7	11.64	23.86	1438
4	Basal ration; phosphates	109.30	162.15	.755	3.40	396.1	170.7	1152.5	10.99	22.53	1357
5	Basal ration; phytin	109.60	163.70	.773	3.54	402.8	177.6	1199.6	11.44	23.43	1412
6	Corn, albumen, gluten, bone flour	109.85	187.50	1.109	4.26	331.8	230	1299.4	44.45	95.59	1439
7	Corn, albumen, gluten, glycerophosphates	109.85	188.65	1.126	4.26	327.0	230	1299.4	44.45	95.59	1439
8	Corn, albumen and gluten	109.75	184.25	1.064	4.26	345.8	230	1299.4	44.45	95.59	1439

[1] Phosphorus supplements and beets not included.
[2] Phosphorus supplements not included.
[3] With the nitrogen of the nucleic acid included as protein this figure would be 188.1.

EXPERIMENT IV, TABLE II. TOTAL FOODS CONSUMED PER LOT OF FIVE PIGS DURING SEVENTY DAYS

Lot No.	Hominy Lbs.	Blood albumen Lbs.	Wheat gluten Lbs.	Corn bran Lbs.	Corn Lbs.	Agar-agar Lbs.	Beets Lbs.	Potassium citrate Lbs.	Supplementary phosphorus Grams P
1	1135.5	34.3	34.3	23.7	.....	1.7	50.5	2.13	.....
2	1158.5	34.9	34.9	24.1	.....	1.8	50.5	2.15	Nucleic acid 252.989
3	1164.6	35.1	35.1	24.3	.....	1.8	50.5	2.15	Glycerophosphate 253.194
4	1098.4	33.2	33.2	22.9	.....	1.6	50.5	2.13	Phosphate 255.477
5	1143.5	34.5	34.5	23.8	.....	1.7	50.5	2.15	Phytin 253.054
6	.....	30.4	30.4	....	1430.7	...	....	....	Bone flour 255.041
7	.....	30.4	30.4	....	1430.7	...	....	....	Glycerophosphate 255.041
8	.. ..	30.4	30.4	....	1430.7	...	....	....	....

EXPERIMENT IV, TABLE III. BALANCE BETWEEN BASIC AND ACID MINERALS IN DAILY RATIONS

Lots	Rations	Daily mineral consumption per pig—Grams							Cubic centimeters normal solution		
		Potassium	Sodium	Calcium	Magnesium	Phosphorus Total and Inorganic	Sulphur	Chlorine	Total acid	Total base	Excess acid
1	Hominy, albumen, gluten, etc., (basal ration) ...	3.4992	.1490	.1284	.5547	T-1.6420 / I-0.3020	3.1765	1.4308	344.46	147.78	196.68
2	Basal ration; nucleic acid.....	3.5628	.2303	.2538	.5721	T-2.4037 / I-0.3095	3.2361	1 4567	398.05	160.62	237.43
3	Basal ration; glycerophosphates.....	3.5653	.1516	1.1069	.5726	T-2.4056 / I-0.3099	3.2569	1.4658	404.73	199.87	204.86
4	Basal ration; phosphates..	3.4292	.1322	1.1286	.5391	T-2.3175 / I-1.0215	3.0715	1.3880	380.28	193.88	186.40
5	Basal ration; phytin.....	3.5588	.1626	.6141	.6155	T-2.3754 / I-0.3178	3.1985	1.4450	390.54	179.10	211.44
6	Corn, albumen, gluten, bone flour.....	6.9899	.1273	1.4189	2.7859	T-6.7097 / I-1.4039	3.7286	1.4917	707.56	483.56	224.00
7	Corn, albumen, gluten, glycerophosphates.....	6.9582	.0829	1.2169	2.7294	T-6.7101 / I-0.6754	3.7286	1.4917	707.59	466.11	241.48
8	Corn, albumen, gluten.....	6.9582	.0829	.2488	2.7294	T-5.9810 / I-0.6752	3.7286	1.4917	660.55	417.83	242.72

EXPERIMENT IV, TABLE IV. SLAUGHTER RECORDS
AVERAGE WEIGHTS OF PARTS

Lot No.	Rations	Final live weight Lbs.	Gross dressed weight Lbs.	Brain Oz.	Heart Oz.	Liver Lbs.	Lungs Oz.	Kidneys Oz.	Spleen Oz.	Leaf fat Lbs.	Bones in ham Lbs.	Fat in ham Lbs.	Muscle in ham Lbs.	Skin of ham Lbs.
1	Hominy, albumen, gluten, etc. (basal ration)	161.2	125.60	3.66	7.49	2.54	24.28	7.03	2.28	5.46	.99	4.07	6.10	.41
2	Basal ration; nucleic acid.....	166.85	127.99	3.73	8.06	2.87	23.09	8.13	2.84	4.68	1.04	4.32	6 55	.43
3	Basal ration; glycerophosphates	169.15	135.05	3.67	8.23	2.19	23.47	6.39	2.53	5.53	1.03	4.22	6.71	.41
4	Basal ration; phosphates.....	162 15	124.27	3.70	8.45	2.55	21.68	7.64	2.43	4.60	1.04	4.00	6.44	.48
5	Basal ration; phytin	163.70	125.76	3.71	8.00	2.58	23.63	8.64	2.64	5.18	.99	4.21	6.25	.40
6	Corn, albumen, gluten, bone flour.....	187.50	146.12	3.81	9.08	2.90	21.70	7.49	3.03	5.13	1.06	4.81	7.37	.49
7	Corn, albumen, gluten, glycerophosphates..... ..	188.65	146.97	3.89	8.53	2.63	22.35	7.12	3.19	5.19	1.05	4.98	7.06	.48
8	Corn, albumen and gluten	184.25	144.13	3.80	8.90	2.33	19.74	7.50	2.88	5.26	1.04	5.01	7.15	.49
9	Check lot, killed at beginning of experiment..	109.40	81.35	3.14	6.33	1.96	11.66	4.78	1.91	5.46	.75	2.20	4.32	.33

EXPERIMENT IV, TABLE V. DATA CONCERNING DEVELOPMENT OF BONES

Lot No.	Rations	Volume C. C.	Length Mm.	Longer transverse diam. Mm.	Shorter transverse diam. Mm.	Breaking strength Lbs.	Ash Grams	Ash per c. c. of volume Grams	Calcium Percent	Magnesium Percent	Phosphorus Percent
	Femur										
1	Hominy, albumen, gluten, etc. (basal ration)	109.6	163	21.1	17.8	354	26.663	.243	37.93	.68	17.09
2	Basal ration; nucleic acid	116.3	172	20.9	18.0	431	33.855	.291	37.80	.68	17.55
3	Basal ration; glycerophosphates	116.4	174	21.3	17.8	390	34.575	.297	38.10	.71	17.45
4	Basal ration; phosphate	119.5	178	20.7	18.3	396	34.885	.292	38.03	.68	17.40
5	Basal ration; phytin	117.9	171	20.6	17.9	316	28.903	.245	38.03	.68	17.15
6	Corn, albumen, gluten, bone flour	119.4	175	20.6	18.6	402	36.343	.304	37.58	.93	18.14
7	Corn, albumen, gluten, glycerophosphates	118.9	175	20.3	17.9	403	34.780	.293	37.42	.92	18.01
8	Corn, albumen and gluten	114.6	174	20.4	17.5	378	32.487	.283	37.58	.95	17.63
9	Check lot, killed at beginning of experiment	81.6	158	17.6	15.6	416	28.008	.343	37.90	.85	18.02
	Tibia										
1	Hominy, albumen, gluten, etc. (basal ration)	65.4	151	18.8	13.3	388	20.442	.313	38.31	.67	17.12
2	Basal ration; nucleic acid	69.0	159	19.0	13.4	486	24.825	.360	38.27	.69	17.62
3	Basal ration; glycerophosphates	69.4	159	19.5	13.7	492	25.844	.372	38.45	.67	17.64
4	Basal ration; phosphates	71.9	164	19.3	13.5	493	25.383	.353	38.08	.70	17.62
5	Basal ration; phytin	71.2	158	19.9	13.7	441	22.210	.312	38.41	.63	17.07
6	Corn, albumen, gluten, bone flour	68.6	160	19.3	13.5	529	25.821	.376	38.11	.83	18.01
7	Corn, albumen, gluten, glycerophosphates	69.7	162	18.4	13.4	476	25.467	.365	38.13	.83	18.11
8	Corn, albumen and gluten	68.6	160	18.7	13.4	450	23.131	.337	38.10	.78	18.04
9	Check lot, killed at beginning of experiment.	51.2	146	17.3	12.0	521	21.007	.410	38.14	.82	17.90

EXPERIMENT IV, TABLE VI. COMPOSITION OF BLOOD—Percent, Fresh Basis

Lot No.	Rations	Moisture	Protein (Nx6.25)	Ether extract	Ash	Total phosphorus	Inorganic phosphorus	Calcium	Magnesium	Potassium	Sodium	Sulphur	Chlorine
1	Hominy, albumen, gluten, etc. (basal ration).	80.86	18.69	.155	.96	.038	.009	.0071	.0036	.172	.24	.145	.27
2	Basal ration; nucleic acid.....	79.58	20.19	.094	.94	.049	.011	.0065	.0039	200	.21	.144	.25
3	Basal ration; glycerophosphates	79.46	20.25	.124	.93	.045	.010	.0062	.0035	.200	.25	.166	.26
4	Basal ration; phosphates..	80.46	19.13	.133	.90	.043	.010	.0070	.0041	.178	.23	.144	.26
5	Basal ration; phytin....	79.79	20.00	.230	.89	.042	.011	.0071	.0034	.200	.25	.131	.24
6	Corn, albumen, gluten, bone flour.....	79.61	20.06	.210	95	.059	.015	.0061	.0047	.210	.26	.130	.25
7	Corn, albumen, gluten, glycerophosphates..	78.56	19.80	.170	1.04	.064	.015	.0081	.0071	.230	.24	.139	.25
8	Corn, albumen and gluten	78.82	20.69	.270	1.00	.059	.016	.0066	.0059	.220	.29	.137	.25
9	Check lot, killed at beginning of experiment.	81.83	16.88	.131	.93	.052	.019	.0085	.0058	.181	.19	.120	.25

EXPERIMENT IV, TABLE VII. COMPOSITION OF TISSUES—Percent

Lot No.	Rations	Moisture	Ether extract	Protein (Nx6.25)	Ash	Total P	Inorganic P	Lecithin P
				Muscle of ham				
1	Hominy, albumen, gluten, etc. (basal ration)	72.07	5.27	21.13	1.05	.224	.101	.033
2	Basal ration; nucleic acid	71.29	5.49	21.50	1.04	.223	.093	.032
3	Basal ration; glycerophosphates	72.23	4.10	21.94	1.07	.224	.106	.031
4	Basal ration; phosphates	71.75	5.21	20.81	1.06	.220	.112	.034
5	Basal ration; phytin	71.69	5.21	21.25	1.05	.230	.095	.035
6	Corn, albumen, gluten, bone flour	73.28	4.38	20.94	1.05	.219	.115	.032
7	Corn, albumen, gluten, glycerophosphates	72.23	5.08	21.44	1.04	.219	.114	.036
8	Corn, albumen and gluten	72.48	4.24	22.06	1.05	.226	.123	.034
9	Check lot, killed at beginning of experiment	73.37	4.95	20.25	1.11	.223	.126	.029
				Fat of ham				
1	Hominy, albumen, gluten, etc. (basal ration)	16.53	78.20	4.00	.207	.039	....	....
2	Basal ration; nucleic acid	15.86	80.17	3.94	.171	.037	....	....
3	Basal ration; glycerophosphates	15.33	80.71	4.31	.175	.038	....	....
4	Basal ration; phosphates	15.76	80.97	3.94	.191	.038	....	....
5	Basal ration; phytin	16.16	79.46	4.38	.190	.040	....	....
6	Corn, albumen, gluten, bone flour	15.15	80.63	3.75	.171	.033	....	....
7	Corn, albumen, gluten, glycerophosphates	16.42	79.79	4.00	.191	.039	....	....
8	Corn, albumen and gluten	14.82	81.23	3.69	.176	.035	....	....
9	Check lot, killed at beginning of experiment	15.14	80.44	4.03	.213	.031	....	....
				Brain				
1	Hominy, albumen, gluten, etc. (basal ration)	78.57	8.82	10.31	1.34	.336	.071	.229
2	Basal ration; nucleic acid	78.34	8.98	10.44	1.37	.342	.068	.227
3	Basal ration; glycerophosphates	78.49	9.01	10.38	1.37	.339	.071	.252
4	Basal ration; phosphates	78.17	9.26	10.50	1.37	.345	.066	.232
5	Basal ration; phytin	78.14	9.36	10.44	1.35	.346	.078	.231
6	Corn, albumen, gluten, bone flour	78.74	9.13	10.19	1.34	.333	.075	.224
7	Corn, albumen, gluten, glycerophosphates	78.34	9.23	10.44	1.37	.328	.077	.236
8	Corn, albumen and gluten	78.29	8.87	10.31	1.38	.346	.070	.233
9	Check lot, killed at beginning of experiment	78.30	8.15	10.63	1.36	.339	.059	.232
				Liver				
1	Hominy, albumen, gluten, etc. (basal ration)	69.26	2.54	18.94	1.41	.392	.081	.112
2	Basal ration; nucleic acid	70.64	2.48	18.81	1.41	.360	.082	.113
3	Basal ration; glycerophosphates	68.90	2.26	19.25	1.42	.367	.084	.127
4	Basal ration; phosphates	70.22	2.74	18.63	1.40	.344	.086	.105
5	Basal ration; phytin	69.78	2.53	18.81	1.39	.357	.083	.124
6	Corn, albumen, gluten, bone flour	68.63	2.31	19.94	1.38	.361	.081	.142
7	Corn, albumen, gluten, glycerophosphates	68.64	2.52	21.38	1.52	.411	.091	.160
8	Corn, albumen and gluten	69.68	2.35	21.06	1.50	.382	.087	.137
9	Check lot, killed at beginning of experiment	70.75	2.66	20.88	1.52	.395	.088	.143
				Kidney				
1	Hominy, albumen, gluten, etc. (basal ration)	80.65	2.18	14.56	1.12	.242	.061	.090
2	Basal ration; nucleic acid	80.97	2.86	14.25	1.08	.247	.065	.100
3	Basal ration; glycerophosphates	79.26	3.01	15.63	1.14	.251	.063	.100
4	Basal ration; phosphates	81.26	2.64	14.25	1.12	.249	.065	.097
5	Basal ration; phytin	81.06	2.76	14.31	1.08	.245	.060	.091
6	Corn, albumen, gluten, bone flour	80.05	2.10	15.75	1.13	.256	.063	.085
7	Corn, albumen, gluten, glycerophosphates	79.31	3.22	15.50	1.10	.253	.068	.096
8	Corn, albumen and gluten	81.19	2.71	14.00	1.43	.236	.064	.083

DISCUSSION OF RESULTS FROM EXPERIMENT IV

In general the differences between the data from the several experimental lots were of lower magnitude than in the previous experiments. More pronounced and certain differences are to be observed between those lots (as a group) receiving corn and those receiving hominy than among those on the hominy basal ration.

The more prominent results in previous experiments had been an apparent superiority of glycerophosphates to the other phosphorus compounds. Evidences of such supposed superiority, or of specific effects of this compound (except with reference to the behavior of the pigs) were very slight in the results from this experiment. It is true that (in Lots 1-5) the glycerophosphate pigs made a slightly greater gain in weight at a slightly lower cost in nutriment, and they also excelled in percentage of gross dressed to live weight; further, the ash per cubic centimeter of volume of the bones excelled all others to a slight extent, as also did the percentage of calcium and magnesium in the bone ash; again, as usual, the muscular tissue of the ham was lower in fat than in other lots; but these differences were not great, and the lack of individual data left us in doubt as to whether or not they were really significant.

In contrasting Lots 1-5, which received the hominy basal ration, with Lots 6-8, which received the corn basal ration, the principal differences of interest were with reference to the bones and the blood. The blood of the corn lots (6-8), for instance, contained less sulphur but more potassium, magnesium, total and inorganic phosphorus and ether extract than did those receiving the hominy basal ration (1-5). Comparing their bones, the corn lots were, as a group, perhaps lower in calcium, and certainly higher in magnesium and phosphorus in the ash than the lots receiving the hominy ration. This is in accord with the fact that the corn rations (6-8) contained much more magnesium and phosphorus than did the hominy rations (1-5).

Among the lots which received corn, No. 6, which also received bone flour, had the thickest bones, the greatest total quantity of ash in the bones, and the greatest amount of ash per cubic centimeter of volume of the bones; while the corn lot which received no phosphorus supplement (No. 8) was lower than the other two in the breaking strength, ash, and ash per cubic centimeter of volume of the bones.

Lot 9, the check lot, which was not fed, had stronger bones than most of their companions after 70 days' experimental feeding. During this feeding the pigs gained in amount of ash in the bones,

but lost in ash per cubic centimeter of volume; and the lots on the hominy ration (1-5) appear to have lost in percent each of calcium, magnesium and phosphorus, a change which could be accounted for only through an increase in carbonate.

In spite of considerable evidence in the foregoing experiments, tending to show that glycerophosphates possess different effects upon the growth of swine from the other phosphorus compounds fed, the results as a whole were not clear-cut and consistent. As regards results from the other compounds there was still less to warrant conclusions. In view of these facts work on this problem was dropped, temporarily, pending the development of methods and apparatus necessary to a different method of attack. In the course of the next year's work, on other problems, we devised a metabolism crate for swine which eliminated the faults of our earlier apparatus through allowing entire freedom of movement, and, at the same time, providing for the accurate collection of urine and feces. After several months of continuously successful work with this new device we decided to compare phosphates with glycerophosphates in a protracted metabolism test, to be terminated by slaughter of the animals and complete individual chemical accounting for the carcasses, the object being especially to determine whether the marked difference in the tolerance of swine for these compounds is due to their respective nutritive values or whether the more or less indefinite and inconstant results of former comparisons were secondary to more superficial effects of these compounds on the states of feeling and activity of the animals.

EXPERIMENT V

Experiment V, conducted during March, April, May, and June, 1913, was a carefully controlled set of balance experiments comparing glycerophosphates and phosphates, and was terminated by a slaughter test and a complete chemical accounting for the bodies of the experimental subjects. Six barrows, all of the same litter, were used in this investigation. Two were killed as controls at the beginning of the study, the other four serving as subjects for the metabolism experiments. With the same low-phosphorus basal ration, two pigs received phosphates, and two glycerophosphates, the mineral bases in these supplements being proportioned, one to another, as in sow's milk. The basal ration was composed, as in the earlier studies, from pearl hominy, blood albumen, wheat gluten, corn bran, agar-agar and sodium chloride. This salt was fed in the proportion of one part to 250 parts of other food.

As in the previous work, much difficulty was experienced in the feeding of the pigs, other than those receiving glycerophosphates, and frequent readjustment of the level of intake of food was necessary. The phosphorus compounds were mixed with the foodstuffs by grinding all together in a Krupp mill. Because of the very limited tolerance of pig No. 5 for the phosphates we were obliged to reduce the food intake of this pig to a low amount; then to facilitate comparison, we reduced the food intake of the glycerophosphate pig No. 4 to the same level. Pigs Nos. 3 and 6, the former receiving glycerophosphates and the latter phosphates, received more food. Very fine grinding, and extensive dilution of the food with water were tried in efforts to solve the problem of feeding the orthophosphates, but without unqualified success. The experiment finally terminated itself in the digestive collapse of one of the pigs (No. 6) receiving phosphates. The experimental data, considerably condensed, appear in the following 24 tables. The discussion of these data will be found on page 62.

Throughout these tables, the six pigs involved received treatment as follows:

Pig 1, killed as a control at beginning of experiment
Pig 2, killed as a control at beginning of experiment
Pig 3, basal ration, glycerophosphates
Pig 4, basal ration, glycerophosphates
Pig 5, basal ration, phosphates
Pig 6, basal ration, phosphates

EXPERIMENT V, TABLE I. TOTAL FOOD AND FECES CONSTÍTUENTS (GRAMS) AND DIGESTION COEFFICIENTS (PERCENT)

Period No.	Pig No.	Food				Feces					Digestibility			
		Protein	Nitrogen free extract	Ether extract	Crude fiber	Protein	Metabolic protein	N-free extract	Ether extract	Crude fiber	Protein	N-free extract	Ether extract	Crude fiber
1	4	3839.916	25301.695	493.132	237.476	283.663	80.476	445.824	84.715	68.490	94.71	98.24	82.82	71.16
1	5	3958.576	26083.562	508.371	244.814	339.775	92.737	477.054	111.158	76.305	93.76	98.17	78.13	68.83
1	6	3371.867	22217.667	433.024	208.530	261.531	68.031	450.990	103.852	64.649	94.26	97.97	76.02	69.00
2	4	2869.450	18829.464	368.295	176.699	200.863	45.375	387.665	77.943	39.727	94.58	97.94	78.84	77.52
2	5	3108.697	20399.275	398.959	191.469	258.750	72.550	425.488	104.771	74.581	94.01	97.92	73.74	61.05
2	6	2708.183	17771.100	347.558	166.801	170.625	38.856	369.446	86.298	59.286	95.13	97.92	75.17	64.46
3	3	1356.263	8919.552	173.819	83.930	97.556	23.994	191.064	29.648	29.787	94.58	97.85	82.94	64.51
3	4	1652.655	10868.789	211.804	102.272	106.594	22.608	244.589	35.189	43.336	94.92	97 75	83.39	57.63
3	5	1718.619	11302.838	220.269	106.361	107.563	26.436	266.456	42.847	50.624	95.28	97.64	80.55	52.40
3	6	1492.591	9816.322	191.300	92.373	82.219	19.842	235.236	36.560	35.238	95.82	97.61	80.89	61.85
4	3	1576.340	10366.903	202.024	97.549	109.463	28.606	208.356	41.221	38.836	94.87	97.99	79.60	60.19
4	4	1595.307	10491.637	204.454	98.723	109.644	22.204	252.529	48.774	41.436	94.52	97.59	76.14	58.03
4	5	1655.515	10887.825	212.181	102.456	122.263	28.247	275.057	51.440	43.907	94.32	97.47	75.76	57.15
4	6	1722.437	11327.946	220.758	106.598	90.044	17.449	260.373	43.221	46.272	95.78	97.70	80.42	56.59
5	3	1584.645	10421.520	203.088	98.063	121.450	29.705	247.456	45.974	47.437	94.21	97.62	77.36	51.63
5	4	1216.316	7999.181	155.883	75.270	72.331	14.697	200.437	26.600	30.370	95.26	97.50	82.94	59.65
5	5	1262.521	8303.222	161.812	78.135	87.238	22.230	233.937	37.980	44.229	94.85	97.18	76.53	43.39
5	6	1729.174	11372.253	221.621	107.015	109.250	23.750	304.368	49.787	60.638	95.06	97.33	77.54	43.34

Pigs 3 and 4 received glycerophosphates; 5 and 6 received phosphates.

EXPERIMENT V, TABLE II. SLAUGHTER RECORDS—Kilograms

Pig No.	Live weight	Gross dressed weight	Blood, fresh	Blood, coagulated	Kidneys	Head	Leaf fat	Spinal cord	Brain	Spleen	Heart
1	49.2	40.1	1.954	1.9325	0.134	2.810	1.598	0.0360	0.0912	0.058	0.168
2	52.2	43.3	2.027	2.0025	0.140	2.900	2.034	0.0340	0.0901	0.054	0.175
3	85.6	71.7	3.056	2.9580	0.159	4.568	2.129	0.0390	0.0932	0.090	0.225
4	96.4	81 1	3.539	3.3014	0.155	5.394	2.466	0.0430	0.1046	0.115	0.250
5	99.4	81.8	3.862	3.6247	0 186	5.675	1.975	0.0482	0.1136	0.125	0.249
6	84.1	69.9	2.617	2.4200	0.178	4.635	1.921	0.0425	0.1015	0.090	0.230

Pig No.	Lungs	Liver	Miscellaneous*	Right half	Left half	Skin	Bones	Flesh	Hair	Hoofs	Back fat Shoulder Middle Rump Mm.
1	0.465	0.715	4.758	17.000	18.400	2.712	3.424	33.132	0.216	0.029	43 37 30
2,	0 361	0.716	4.856	18.400	19.600	3.639	3.450	35.013	0.245	0.029	50 38 37
3	0.407	0.870	5.447	33.000	31.600	5.052	5.085	59.868	0.360	0.072	58 48 57
4	0.539	0.820	6 203	36.100	36.800	4.902	6.032	68.345	0.356	0.087	60 38 45
5	0.497	1.378	7.463	37.100	36.600	4 631	6 186	68.885	0.345	0.075	70 50 57
6	0.276	1.114	6.211	30.900	32 100	3.875	5 206	59.179	0.316	0.069	60 47 55

Pigs 1 and 2 were checks, killed at the beginning of the experiment; 3 and 4 received glycerophosphates; 5 and 6 received phosphates.
*Under "Miscellaneous" are included all parts not otherwise accounted for.

EXPERIMENT V, TABLE III. RELATION OF PARTS AND ORGANS TO EMPTY LIVE WEIGHT*

Pig No.	Computed empty live weight Kg.	Gross dressed weight	Blood, fresh	Kidneys	Leaf fat	Spinal cord	Brain	Spleen	Heart	Lungs	Liver	Bones	Flesh and skin	Hair and hoofs
1	46.225	.867	.0422	.00289	.0345	.00078	.00197	.00125	.00363	.0100	.01540	.0741	.7750	.00530
2	49.260	.879	.0411	.0028	.0412	.00069	.00182	.00109	.00355	.00732	.01450	.0700	.7840	.00557
3	78.941	.908	.0387	.00201	.0269	.00049	.00118	.00114	.00285	.00515	.01102	.0644	.8220	.00548
4	89.464	.906	.0395	.00173	.0275	.00048	.00116	.00128	.00279	.0060	.00916	.0674	.8180	.00494
5	91.447	.894	.0422	.00203	.0215	.00052	.00124	.00136	.00272	.00543	.01506	.0676	.8030	.00459
6	77.473	.902	.0337	.00229	.0247	.00055	.00131	.00115	.00296	.00356	.01430	.0671	.8130	.00497

*Weights of parts and organs divided by empty live weight. Pigs 1 and 2 were checks, killed at the beginning of the experiment; 3 and 4 received glycerophosphates; 5 and 6 received phosphates.

EXPERIMENT V, TABLE IV. TOTAL AMOUNTS OF CONSTITUENTS IN THE BODIES OF SWINE AS AFFECTED BY PHOSPHATES AND GLYCEROPHOSPHATES—Kilograms

Pig No.	Treatment	Moisture	Nitrogen	Ether extrct	Ash	Total phos-phorus	Inorganic phos-phorus	Organic phos-phorus	Lecithin phos-phorus	Calcium of skeleton	Magne-sium of skeleton	Phos-phorus of skeleton
1	Check....	20.3143	0.8885	19.5328	1.0227	0.1760	.0231	.0210	.0076	.2779	.0063	.1309
2	Check..	20.4863	0.9109	22.0205	1.0915	0.1884	.0248	.0195	.0100	.3013	.0067	.1428
3	Glycerophosphates	31.7093	1.5482	36.0285	1.3199	0.2202	.0400	.0270	.0115	.3269	.0067	.1525
4	Glycerophosphates	33.3671	1.6722	44.1737	1.6153	0.2769	.0444	.0291	.0119	.4316	.0090	.2031
5	Phosphates.....	37.3646	1.8526	41.2521	1.7059	0.2926	.0476	.0342	.0231	.4503	.0088	.2106
6	Phosphates.....	28.0649	1.5200	38.7566	1.3854	0.2413	.0394	.0285	.0134	.3765	.0070	.1737

EXPERIMENT V, TABLE V. COMPOSITION OF THE BODIES OF SWINE AS AFFECTED BY PHOSPHATES AND GLYCEROPHOSPHATES

Percentage of Computed Empty Live Weight

Pig No.	Treatment	Moisture	Nitrogen	Ether extract	Ash[1]	Total phosphorus	Inorganic phosphorus[1] (water soluble)	Organic phosphorus[1,2]	Lecithin[1] phosphorus	Calcium of skeleton	Magnesium of skeleton	Phosphorus of skeleton
1	Check.....	43.947	1.922	42.256	2.212	.381	.0500	.0454	.0164	.601	.0136	.283
2	Check.....	41.588	1.849	44.703	2.216	.382	.0503	.0396	.0203	.612	.0136	.290
3	Glycerophosphates	40.168	1.961	45.640	1.672	.279	.0507	.0342	.0146	.414	.0085	.193
4	Glycerophosphates	37.297	1.869	49.376	1.806	.310	.0496	.0325	.0133	.482	.0101	.227
5	Phosphates..... ...	40.859	2.026	45.110	1.865	.320	.0521	.0374	.0253	.492	.0096	.230
6	Phosphates....	36.225	1.962	50.026	1.788	.311	.0509	.0368	.0173	.486	.0090	.224

[1]Hair and hoof not included.
[2]Skeleton not included.

EXPERIMENT V, TABLE VI. COMPOSITION OF THE FLESH OF SWINE AS AFFECTED BY PHOSPHATES AND GLYCEROPHOSPHATES

Percent

Pig No.	Treatment	Fresh basis								Fat- and water-free basis			
		Moisture	Nitrogen	Ether extract	Ash	Total phosphorus	Inorganic phosphorus	Organic phosphorus	Lecithin phosphorus	Total phosphorus	Inorganic phosphorus	Organic phosphorus	Lecithin phosphorus
1	Control	37.8590	1.4960	52.8550	0.5890	0.0990	0.0560	0.0430	0.0124	1.0661	.6031	.4631	.1335
2	Control	35.1340	1.4150	55.1330	0.5560	0.0929	0.0566	0.0363	0.0174	.9545	.5815	.3730	.1788
Ave.		36.4965	1.4555	53.9940	0.5725	0.0960	0.0563	0.0397	0.0149	1.0103	.5923	.4181	.1562
3	Basal ration; glycerophosphates	34.6320	1.4950	55.1900	0.5626	0.0889	0.0550	0.0339	0.0140	.8735	.5404	.3331	.1376
4	Basal ration; glycerophosphates	31.7320	1.4030	58.7490	0.5213	0.0853	0.0527	0.0326	0.0106	.8961	.5536	.3425	.1114
Ave.		33.1820	1.4490	56.9695	0.5420	0.0871	0.0539	0.0333	0.0123	.8848	.5470	.3378	.1245
5	Basal ration; phosphates	35.2260	1.6320	54.5440	0.5620	0.0931	0.0539	0.0392	0.0247	.9101	.5269	.3832	.2414
6	Basal ration; phosphates	31.0160	1.5415	59.2470	0.5089	0.0887	0.0541	0.0346	0.0168	.9110	.5556	.3553	.1725
Ave.		33.1210	1.5868	56.8955	0.5355	0.0909	0.0540	0.0369	0.0208	.9106	.5413	.3693	.2070

EXPERIMENT V, TABLE VII. COMPOSITION OF THE SKELETON OF SWINE AS AFFECTED BY PHOSPHATES AND GLYCERO-PHOSPHATES—Percent

Pig No.	Treatment	Fresh basis								Fat- and water-free basis			
		Moisture	Nitrogen	Ether extract	Ash	Calcium	Magnesium	Total phosphorus	Lecithin phosphorus	Calcium	Magnesium	Total phosphorus	Lecithin phosphorus
1	Control	41.8880	2.9570	14.6730	21.4830	8.1149	0.1829	3.8216	0.0091	18.6811	.4211	8.7976	.0209
2	Control	42.8190	3.0960	15.6480	23.1060	8.7335	0.1937	4.1379	0.0112	21.0279	.4664	9.9629	.0270
Ave.		42.3535	3.0265	15.1605	22.2945	8.4242	0.1883	3.9798	0.0102	19.8545	.4438	9.3803	.0240
3	Basal ration; glycerophosphates	40.5350	2.8840	21.6910	17.0315	6.4300	0.1320	3.0000	0.0062	17.0223	.3494	7.9420	0164
4	Basal ration; glycerophosphates	42.2390	2.8850	21.7690	18.7730	7.1547	0.1489	3.3672	0.0155	19.8786	.4137	9.3554	.0431
Ave.		41.3870	2.8845	21.7300	17.9023	6.7924	0.1405	3.1836	0.0109	18.4505	.3816	8.6487	.0298
5	Basal ration; phosphates	40.8430	2.7990	20.0730	19.1310	7.2790	0.1420	3.4050	0.0185	18.6240	.3633	8.7120	.0473
6	Basal ration; phosphates	38.1970	2.7810	23.9380	18.6920	7.2330	0.1345	3.3370	0.0074	19.1021	.3552	8.8129	.0195
Ave.		39.5200	2.7900	22.0055	18.9115	7.2560	0.1383	3.3710	0.0130	18.8631	.3593	8.7625	.0334

EXPERIMENT V, TABLE VIII. COMPOSITION OF THE BLOOD OF SWINE AS AFFECTED BY PHOSPHATES AND GLYCEROPHOSPHATES—Percent

Pig No.	Treatment	Fresh basis								Water-free basis			
		Moisture	Nitrogen	Ether extract	Ash	Total phosphorus	Inorganic phosphorus	Organic phosphorus	Lecithin phosphorus	Total phosphorus	Inorganic phosphorus	Organic phosphorus	Lecithin phosphorus
1	Control	82.0130	2.9777	0.2237	0.9220	0.0509	0.0137	0.0372	0.0058	0.2830	0.0762	0.2068	0.0322
2	Control	82.1420	2.8470	0.2377	0.9470	0.0506	0.0139	0.0367	0.0059	0.2833	0.0778	0.2055	0.0330
Average. ...		82.0775	2.9124	0.2307	0.9345	0.0508	0.0138	0.370	0.0059	0.2832	0.0770	0.2062	0.0326
3	Basal ration; glycerophosphates..	77.8230	3.5770	0.2060	1.0467	0.0535	0.0143	0.0392	0.0050	0.2412	0.0645	0.1767	0.0227
4	Basal ration; glycerophosphates..	76.3820	3.8290	0.3389	1.0716	0.0480	0.0125	0.0355	0.0118	0.2032	0.0529	0.1503	0.0499
Average....		77.1025	3.7030	0.2725	1.0592	0.0508	0.0134	0.0374	0.0084	0.2222	0.0587	0.1635	0.0363
5	Basal ration; phosphates.....	80.3770	3.1170	0.6875	0.9995	0.0454	0.0136	0.0318	0.0062	0.2330	0.0698	0.1632	0.0318
6	Basal ration; phosphates.....	77.2980	3.7150	0.5996	1.1060	0.0516	0.0136	0.0380	0.0060	0.2272	0.0599	0.1673	0.0266
Average.....		78.8375	3.4160	0.6436	1.0528	0.0485	0.0136	0.0349	0.0061	0.2301	0.0649	0.1653	0.0292

EXPERIMENT V, TABLE IX. COMPOSITION OF THE BRAIN OF SWINE AS AFFECTED BY PHOSPHATES AND GLYCERO-PHOSPHATES—Percent

Pig No.	Treatment	Fresh basis								Water-free basis			
		Moisture	Nitrogen	Ether extract	Ash	Total phosphorus	Inorganic phosphorus	Organic phosphorus	Lecithin phosphorus	Total phosphorus	Inorganic phosphorus	Organic phosphorus	Lecithin phosphorus
1	Control	77.0020	1 6790	10.3660	1.5080	0.3529	0.0536	0.2993	0.2558	1.5345	0.2331	1.3014	1.1123
2	Control	77.1870	1.7010	9.9890	1.5430	0.3489	0.0682	0.2807	0.2493	1.5294	0.2989	1.2305	1.0927
Ave.		77.0945	1.6900	10.1775	1.5255	0.3509	0.0609	0.2900	0.2526	1.5320	0.2660	1.2660	1.1025
3	Basal ration; glycerophosphates	76.9100	1.8500	10.0990	1.5600	0.3557	0.0901	0.2656	0.2450	1.5405	0.3902	1.1503	1.0611
4	Basal ration; glycerophosphates	77.2440	1.7065	10.1270	1.5270	0.3442	0.0833	0.2609	0.2461	1.5125	0.3661	1.1464	1.0815
Ave.		77.0770	1 7783	10.1130	1.5435	0.3500	0.0867	0.2633	0.2456	1.5265	0.3782	1.1484	1.0713
5	Basal ration; phosphates	78.0040	1.6790	9.2180	1.4810	0.3378	0.0819	0.2559	0.2411	1.5357	0.3723	1.1634	1.0961
6	Basal ration; phosphates	77.3650	1.6960	9.6530	1.5170	0.3341	0.0813	0.2528	0.2396	1.4760	0.3591	1.1169	1.0585
Ave.		77.6845	1.6875	9.4355	1.4990	0.3360	0.0816	0.2544	0.2404	1.5059	0.3657	1.1402	1.0773

METABOLISM OF SWINE ON A LOW-PHOSPHORUS RATION WITHOUT MINERAL SUPPLEMENTS

EXPERIMENT V, TABLE X. Period I, 15 Days. Average Daily Mineral Balances—Grams

Pig No.	Live weight Initial / Final / Kilos	Average daily rations / Total food	Sodium	Potassium	Calcium	Magnesium	Sulphur	Phosphorus	Chlorine	Nitrogen
			Food	Food	Food	Food	Food	Food	Food	Food
			Urine	Urine	Urine	Urine	Urine	Urine	Urine	Urine
			Feces	Feces	Feces	Feces	Feces	Feces	Feces	Feces
			Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance
3*	61.6 62.4	Total food..... 2032 No supplemental phosphorus	3.859 1.509	2.796 1.043	2.711 1.695	0.756 0.428	4.375 0.991	2.042 0.030	6.476 5.670	36.275 4.996
4	70.6 79.8	Total food..... 2291 No supplemental phosphorus	4.353 2.330 0.723 +1.300	3.155 1.407 0.320 +1.428	3.039 1.773 1.006 +0.260	0.838 0.484 0.212 +0.142	4.880 2.375 0.531 +1.974	2.306 0.021 0.780 +1.505	7.311 5.123 0.010 +2.178	40.958 11.641 3.026 +26.291
5	72.8 81.6	Total food..... 2362 No supplemental phosphorus	4.488 2.845 0.686 +0.957	3.252 1.443 0.458 +1.351	3.133 1.377 1.110 +0.646	0.864 0.374 0.237 +0.253	5.031 2.126 0.567 +2.338	2.377 0.032 0.769 +1.576	7.536 6.113 0.016 +1.407	42.223 9.528 3.624 +29.071
6	62.0 69.3	Total food..... 2012 No supplemental phosphorus	3.823 3.170 0.425 +0.228	2.770 0.947 0.712 +1.111	2.668 1.470 1.074 +0.124	0.736 0.340 0.205 +0.191	4.285 1.908 0.485 +1.892	2.025 0.031 0.839 +1.155	6.419 5.585 0.011 +0.823	35.965 8.910 2.790 +24.265

*7 days only.

METABOLISM OF SWINE AS AFFECTED BY PHOSPHATES AND GLYCEROPHOSPHATES

EXPERIMENT V, TABLE XI. Period II, 21 Days. Average Daily Mineral Balances—Grams

Pig No.	Live weight Initial / Final Kg.	Average daily ration Total food, and supplemental phosphorus	Sodium Food / Urine / Feces / Balance	Potassium Food / Urine / Feces / Balance	Calcium Food / Urine / Feces / Balance	Magnesium Food / Urine / Feces / Balance	Sulphur Food / Urine / Feces / Balance	Phosphorus Food / Urine / Feces / Balance	Chlorine Food / Urine / Feces / Balance	Nitrogen Food / Urine / Feces / Balance
3*	62.4 68.4	Total food.....1037 P as glycerophosphate.....0.297	2.047	1.498	1.607	0.379	2.132	1.341	3.312	18.565
4	79.8 83.4	Total food.....1121 P as glycerophosphate.....0.341	2.409 1.784 0.396 +0.229	1.763 0.947 0.215 +0.601	1.886 0.135 0.568 +1.183	0.445 0.196 0.125 +0.124	2.511 1.235 0.262 +1.014	1.571 0.253 0.368 +0.950	3.901 3.381 0.005 +0.515	21.863 5.702 1.530 +14.631
5	81.6 86.2	Total food.....1322 P as phosphate.....0.370	2.607 2.017 0.380 +0.210	1.907 0.825 0.577 +0.505	2.031 0.130 0.578 +1.323	0.481 0.187 0.165 +0.129	2.721 1.314 0.281 +1.126	1.704 0.125 0.487 +1.092	4.224 3.689 0.129 +0.406	23.686 5.801 1.971 +15.914
6	69.3 75.0	Total food.....1152 P as phosphate.....0.322	2.271 1.745 0.376 +0.150	1.662 0.849 0.201 +0.612	1.769 0.109 0.538 +1.122	0.419 0.175 0.124 +0.120	2.370 1.233 0.219 +0.918	1.485 0.153 0.349 +0.983	3.680 3.414 0.004 +0.262	20.635 5.520 1.300 +13.815

*11 days only.

METABOLISM OF SWINE AS AFFECTED BY PHOSPHATES AND GLYCEROPHOSPHATES

EXPERIMENT V, TABLE XII. Period III, 10 Days. Average Daily Mineral Balances—Grams

Pig No.	Live weight Initial / Final Kg.	Average daily ration Total food, and supplemental phosphorus	Sodium Food / Urine / Feces / Balance	Potassium Food / Urine / Feces / Balance	Calcium Food / Urine / Feces / Balance	Magnesium Food / Urine / Feces / Balance	Sulphur Food / Urine / Feces / Balance	Phosphorus Food / Urine / Feces / Balance	Chlorine Food / Urine / Feces / Balance	Nitrogen Food / Urine / Feces / Balance
3	68.4 72.4	Total food. .....1208.5 P as glycerophosphate..... 0.295	1.467 0.740 0.439 +0.288	1.738 0.669 0.421 +0.648	0.416 0.049 0.186 +0.181	0.467 0.151 0.075 +0.241	2.591 1.130 0.328 +1.133	1.517 0.156 0.400 +0.961	2.458 2.158 0.004 +0.296	21.700 5.290 1.561 +14.849
4	83.4 88.8	Total food.....1472.6 P as glycerophosphate..... 0.359	1.788 1.054 0.252 +0.482	2.118 0.747 0.321 +1.050	0.507 0.058 0.187 +0.262	0.568 0.191 0.086 +0.291	3.157 1.411 0.367 +1.379	1.848 0.536 0.208 +1.104	2.300 2.459 0.007 −0.166	26.442 6.959 1.706 +17.777
5	86.2 92.2	Total food.....1530.6 P as phosphate..... 0.373	1.857 0.969 0.148 +0.740	2.200 0.899 0.585 +0.716	0.516 0.052 0.208 +0.256	0.591 0.163 0.120 +0.308	3.283 1.376 0.354 +1.553	1.922 0.449 0.220 +1.253	3.113 2.549 0.007 +0.557	27.497 6.807 1.721 +18.969
6	75.0 79.0	Total food.....1329.3 P as phosphate..... 0.324	1.612 1.169 0.212 +0.231	1.910 0.453 0.264 +1.193	0.448 0.034 0.216 +0.198	0.513 0.165 0.101 +0.247	2.851 1.254 0.326 +1.271	1.670 0.493 0.175 +1.002	2.704 2.314 0.005 +0.385	23.881 6.426 1.316 +16.139

METABOLISM OF SWINE AS AFFECTED BY PHOSPHATES AND GLYCEROPHOSPHATES

EXPERIMENT V, TABLE XIII. Period IV, 10 Days. Average Daily Mineral Balances—Grams

Pig No.	Live weight Initial / Final Kg.	Average daily rations Total food, and supplemental phosphorus	Sodium Food / Urine / Feces / Balance	Potassium Food / Urine / Feces / Balance	Calcium Food / Urine / Feces / Balance	Magnesium Food / Urine / Feces / Balance	Sulphur Food / Urine / Feces / Balance	Phosphorus Food / Urine / Feces / Balance	Chlorine Food / Urine / Feces / Balance	Nitrogen Food / Urine / Feces / Balance
3	72.4 77.2	Total food.....1404.6 P as glycerophosphate..... 0.343	1.705 0.607 0.423 +0.675	2.020 0.640 0.488 +0.892	0.483 0.037 0.138 +0.308	0.542 0.151 0.077 +0.314	3.012 1.228 0.364 +1.420	1.763 0.221 0.393 +1.149	2.857 2.151 0.005 +0.701	25.221 5.944 1.751 +17.526
4	88.8 90.7	Total food.....1421.5 P as glycerophosphate..... 0.347	1.726 1.560 0.318 −0.152	2.044 0.432 0.288 +1.324	0.489 0.050 0.159 +0.280	0.549 0.179 0.081 +0.289	3.048 1.308 0.377 +1.363	1.784 0.541 0.193 +1.050	2.891 2.416 0.005 +0.470	25.525 6.612 1.754 +17.159
5	92.2 94.6	Total food.....1474.4 P as phosphate..... 0.360	1.788 1.983 0.107 −0.302	2.119 0.365 0.571 +1.183	0.497 0.049 0.176 +0.272	0.569 0.181 0.116 +0.272	3.163 1.536 0.381 +1.246	1.852 0.536 0.220 +1.096	2.999 2.625 0.008 +0.366	26.488 7.281 1.956 +17.251
6	79.0 84.2	Total food.....1534.0 P as phosphate..... 0.374	1.861 1.578 0.120 +0.163	2.204 0.518 0.531 +1.155	0.517 0.037 0 160 +0.320	0.592 0.182 0.100 +0.310	3.290 1.455 0.338 +1.497	1.927 0.478 0.195 +1.254	3.120 2.594 0.004 +0.522	27.558 7.337 1.441 +18.780

METABOLISM OF SWINE AS AFFECTED BY PHOSPHATES AND GLYCEROPHOSPHATES

EXPERIMENT V, TABLE XIV. Period V, 10 Days. Average Daily Mineral Balances—Grams

Pig No.	Live weight Initial / Final Kg.	Average daily ration Total food, and supplemental phosphorus		Sodium	Potassium	Calcium	Magnesium	Sulphur	Phosphorus	Chlorine	Nitrogen
				Food	Food	Food	Food	Food	Food	Food	Food
				Urine	Urine	Urine	Urine	Urine	Urine	Urine	Urine
				Feces	Feces	Feces	Feces	Feces	Feces	Feces	Feces
				Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance
3	77.2	Total food	1412.0	1.714	2.031	0.486	0.545	3.027	1.772	2.872	25.354
	81.4	P as glycerophosphate	0.345	0.698	0.316	0.033	0.165	1.264	0.219	2.271	6.188
				0.501	0.664	0.146	0.101	0.412	0.486	0.005	1.943
				+0.515	+1.051	+0.307	+0.279	+1.351	+1.067	+0.596	+17.223
4	90.7	Total food	1083.8	1.316	1.559	0.373	0.418	2.324	1.360	2.204	19.461
	93.0	P as glycerophosphate	0.264	0.645	0.639	0.035	0.147	1.085	0.501	1.850	5.406
				0.181	0.201	0.124	0.065	0.283	0.128	0.003	1.157
				+0.490	+0.719	+0.214	+0.206	+0.956	+0.731	+0.351	+12.898
5	94.6	Total food	1124.4	1.364	1.616	0.379	0.434	2.412	1.412	2.287	20.200
	97.0	P as phosphate	0.274	0.693	0.397	0.034	0.136	1.113	0.480	1.780	5.126
				0.081	0.703	0.147	0.091	0.291	0.219	0.006	1.396
				+0.590	+0.516	+0.198	+0.207	+1.008	+0.713	+0.501	+13.678
6	84.2	Total food	1540.0	1.868	2.213	0.519	0.594	3.303	1.934	3.132	27.666
	89.6	P as phosphate	0.376	1.131	0.453	0.018	0.184	1.540	0.584	2.430	6.890
				0.112	0.953	0.205	0.146	0.404	0.310	0.010	1.748
				+0.625	+0.807	+0.296	+0.264	+1.359	+1.040	+0.692	+19.028

METABOLISM OF SWINE AS AFFECTED BY PHOSPHATES AND GLYCEROPHOSPHATES

EXPERIMENT V, TABLE XV. Period VI, 10 Days. Average Daily Food and Urine Constituents—Grams

Pig No.	Live weight Initial / Final Kg.	Average daily rations — Total food, and supplemental phosphorus	Sodium Food	Sodium Urine	Potassium Food	Potassium Urine	Calcium Food	Calcium Urine	Magnesium Food	Magnesium Urine	Sulphur Food	Sulphur Urine	Phosphorus Food	Phosphorus Urine	Chlorine Food	Chlorine Urine	Nitrogen Food	Nitrogen Urine
3	81.4	Total food 1327.4	1.612		1.909		0.457		0.512		2.846		1.666		2.670		23.835	
	85.6	P as glycerophosphate..... 0 324	1.129		0.338		0.024		0.169		1.344		0.354		2.176		7.264	
4	93.0	Total food..... ... 1111.0	1.349		1.598		0.382		0.429		2.382		1.394		2.260		19.949	
	96.4	P as glycerophosphate..... .... 0.271	1.042		0.544		0.026		0.147		1.205		0.498		1.982		6.113	
5	97.0	Total food..... .1096.9	1.331		1 576		0.370		0.423		2.353		1.378		2.231		19.706	
	99.4	P as phosphate.. ..... 0.268	1.340		0.366		0.040		0.132		1.207		0.545		2.132		6.247	
6*	89.6	Total food.....1110.0	1 346		1.595		0.374		0.428		2.381		1.394		2.258		19.941	
	84.1	P as phosphate..... 0.271																

*7 days only.

METABOLISM OF SWINE AS AFFECTED BY PHOSPHATES AND GLYCEROPHOSPHATES

EXPERIMENT V, TABLE XVI. Period II. Average Daily Mineral Balances Per Kilogram of Live Weight—Grams

Pig No.	Av. live weight in Kg.	Average daily rations Total food, and supplemental phosphorus	Sodium Food Urine Feces Balance	Potassium Food Urine Feces Balance	Calcium Food Urine Feces Balance	Magnesium Food Urine Feces Balance	Sulphur Food Urine Feces Balance	Phosphorus Food Urine Feces Balance	Chlorine Food Urine Feces Balance	Nitrogen Food Urine Feces Balance
4	81.6	Total food,..... ..... 1121 P as glycerophosphate 0.341	0.030 0.022 0.005 +0.003	0.022 0.012 0.003 +0.007	0.023 0.002 0.007 +0.014	0.005 0.002 0.002 +0.002	0.031 0.015 0.003 +0.012	0.019 0.003 0.005 +0.012	0.048 0.041 0.000 +0.006	0.268 0.070 0.019 +0.179
5	83.9	Total food... ..... 1322 P as phosphate..... .....0.370	0.031 0.024 0.005 +0.003	0.023 0.010 0.007 +0.006	0.024 0.002 0.007 +0.016	0.006 0.002 0.002 +0.002	0.032 0.016 0.003 +0.013	0.020 0.001 0.006 +0.013	0.050 0.044 0.002 +0.005	.282 0.069 0.023 +0.190
6	72.2	Total food..... 1152 P as phosphate.....0.322	0.031 0.024 0.005 +0.002	0.023 0.012 0.003 +0.008	0.025 0.002 0.007 +0.016	0.006 0.002 0.002 +0.002	0.033 0.017 0.003 +0.013	0.021 0.002 0.005 +0.014	0.051 0.047 0.000 +0.004	0.286 0.076 0.018 +0.191

Apparent inconsistencies in balances in the above and the three following tables are due to dropping figures of less than 5 in the fourth decimal place, and considering figures of 5 or more in the fourth place as 1 in the third place.

METABOLISM OF SWINE AS AFFECTED BY PHOSPHATES AND GLYCEROPHOSPHATES

EXPERIMENT V, TABLE XVII. Period III, 10 Days. Balance Data Per Kilogram of Live Weight—Grams

Pig No.	Average live weight in Kg.	Average daily rations Total food, and supplemental phosphorus	Sodium Food Urine Feces Balance	Potassium Food Urine Feces Balance	Calcium Food Urine Feces Balance	Magnesium Food Urine Feces Balance	Sulphur Food Urine Feces Balance	Phosphorus Food Urine Feces Balance	Chlorine Food Urine Feces Balance	Nitrogen Food Urine Feces Balance
3	70.4	Total food.....1208.5 P as glycerophosphate..... ... 0.295	0.021 0.011 0.006 +0.004	0.025 0.010 0.006 +0.009	0.006 0.001 0.003 +0.003	0.007 0.002 0.001 +0.003	0.037 0.016 0.005 +0.016	0.022 0.002 0.006 +0.014	0.035 0.031 0.000 +0.004	0.308 0.075 0.022 +0.209
4	86.1	Total food.....1472.6 P as glycerophosphate..... .... 0.359	0.021 0.012 0.003 +0.006	0.025 0.009 0.004 +0.012	0.006 0.001 0.002 +0.003	0.007 0.002 0.001 +0.003	0.037 0.016 0.004 +0.016	0.021 0.006 0.002 +0.013	0.027 0.029 0.000 −0.00	0.307 0.081 0.020 +0.206
5	89.2	Total food... ....1530.6 P as phosphate..... 0.373	0.021 0.011 0.002 +0.008	0.025 0.010 0.007 +0.008	0.006 0.001 0.002 +0.003	0.007 0.002 0.001 +0.003	0.037 0.015 0.004 +0.017	0.022 0.005 0.002 +0.014	0.035 0.029 0.000 +0.006	0.308 0.076 0.019 +0.213
6	77.0	Total food.....1329.3 P as phosphate 0.324	0.021 0.015 0.003 +0.003	0.025 0.006 0.003 +0.015	0.006 0.000 0.003 +0.003	0.007 0.002 0.001 +0.003	0.037 0.016 0.004 +0.017	0.022 0.006 0.002 +0.013	0 035 0.030 0.000 +0.005	0.310 0.083 0.017 +0.210

METABOLISM OF SWINE AS AFFECTED BY PHOSPHATES AND GLYCEROPHOSPHATES

EXPERIMENT V, TABLE XVIII. Period IV, 10 Days. Balance Data Per Kilogram of Live Weight—Grams

Pig No.	Av. live weight in Kg.	Average daily rations Total food, and supplemental phosphorus	Sodium Food Urine Feces Balance	Potassium Food Urine Feces Balance	Calcium Food Urine Feces Balance	Magnesium Food Urine Feces Balance	Sulphur Food Urine Feces Balance	Phosphorus Food Urine Feces Balance	Chlorine Food Urine Feces Balance	Nitrogen Food Urine Feces Balance
3	74.8	Total food.....1404.6 P as glycerophosphate 0.343	0.023 0.008 0.006 +0.009	0.027 0.009 0.007 +0.012	0 006 0.000 0.002 +0.004	0.007 0.002 0.001 +0.004	0.040 0.016 0.005 +0.019	0.024 0.003 0.005 +0.015	0.038 0.029 0.000 +0.009	0.337 0.079 0.023 +0.234
4	89.8	Total food.....1421.5 P as glycerophosphate 0.347	0.019 0.017 0.004 −0.002	0.023 0.005 0.003 +0.015	0.005 0.001 0.002 +0.003	0.006 0.002 0.001 +0.003	0.034 0.015 0.004 +0.015	0.020 0.006 0.002 +0.012	0.032 0.027 0.000 +0.005	0.284 0.074 0.020 +0.191
5	93.4	Total food..... ...1474.4 P as phosphate..... 0.360	0.019 0.021 0.001 −0.003	0.023 0.004 0.006 +0.013	0.005 0.001 0 002 +0.003	0.006 0.002 0.001 +0.003	0.034 0.016 0.004 +0.013	0.020 0.006 0.002 +0.012	0.032 0.028 0.000 +0.004	0.284 0.078 0.021 +0.185
6	81.6	Total food.....1534.0 P as phosphate..... 0.374	0.023 0.019 0.001 +0.002	0.027 0.006 0.007 +0.014	0.006 0.000 0.002 +0.004	0.007 0.002 0.001 +0.004	0.040 0.018 0.004 +0.018	0.024 0.006 0 002 +0.015	0.038 0.032 0.000 +0.006	0.338 0.090 0.018 +0.230

METABOLISM OF SWINE AS AFFECTED BY PHOSPHATES AND GLYCEROPHOSPHATES

EXPERIMENT V, TABLE XIX. Period V, 10 Days. Balance Data Per Kilogram of Live Weight—Grams

Pig No.	Average live weight in Kg.	Average daily rations Total food, and supplemental phosphorus	Sodium Food Urine Feces Balance	Potassium Food Urine Feces Balance	Calcium Food Urine Feces Balance	Magnesium Food Urine Feces Balance	Sulphur Food Urine Feces Balance	Phosphorus Food Urine Feces Balance	Chlorine Food Urine Feces Balance	Nitrogen Food Urine Feces Balance
3	79.3	Total food.....1412.0 P as glycerophosphate..... 0.345	0.022 0.009 0.006 +0.006	0.026 0.004 0.008 +0.013	0.006 0.000 0.002 +0.004	0.007 0.002 0.001 +0.004	0.038 0.016 0.005 +0.017	0.022 0.003 0.006 +0.013	0.036 0.029 0.000 +0.008	0.320 0.078 0.025 +0.217
4	91.9	Total food.....1083.8 P as glycerophosphate..... 0.264	0.014 0.007 0.002 +0.005	0.017 0.007 0.002 +0.008	0.004 0.000 0.001 +0.002	0.005 0.002 0.001 +0.002	0.025 0.012 0.003 +0.010	0.015 0.005 0.001 +0.008	0.024 0.020 0.000 +0.004	0.212 0.059 0.013 +0.140
5	85.8	Total food.....1124.4 P as phosphate..... 0.274	0.016 0.008 0.001 +0.007	0.019 0.005 0.008 +0.006	0.004 0.000 0.002 +0.002	0.005 0.002 0.001 +0.002	0.02 0.013 0.003 +0.012	0.016 0.006 0.003 +0.008	0.027 0.021 0.000 +0.006	0.235 0.060 0.016 +0.159
6	86.9	Total food.....1540.0 P as phosphate..... 0.376	0.021 0.013 0.001 +0.007	0.025 0.005 0.011 +0.009	0.006 0.000 0.002 +0.003	0.007 0.002 0.002 +0.003	0.038 0.018 0.005 +0.016	0.022 0.007 0.004 +0.012	0.036 0.028 0.000 +0.008	0.318 0.079 0.020 +0.219

Average Daily Intake of Mineral Elements, and Partition of Outgo Between Urine and Feces—Urine and Feces Together Equal 100 Percent. Intake (upper figure) in Grams; Urine (middle figure) and Feces (lower figure) in Percent of Outgo Experiment V, Table XX. Period II, 21 Days

Pig No.	Rations	Sodium	Potassium	Calcium	Magnesium	Sulphur	Phosphorus	Chlorine
		Intake Urine Feces	Intake Urine Feces	Intake Urine Feces	Intake Urine Feces	Intake Urine Feces	Intake Urine Feces	Intake Urine Feces
4	Basal ration; glycerophosphates	2.409 81.8 18.2	1.763 81.5 18.5	1.886 19.2 80.8	0.445 61.1 38.9	2.511 82.5 17.5	1.571 40.7 59.3	3.901 99.9 00.1
5	Basal ration; phosphates	2.607 84.1 15.9	1.907 58.8 41.2	2.031 18.4 81.6	0 481 53.1 46.9	2.721 82.4 17.6	1.704 20.4 79.6	4 224 96.6 3.4
6	Basal ration; phosphates	2.271 82.3 17.7	1.662 80.9 19.1	1.769 16.8 83.2	0.419 58.5 41.5	2.370 84.9 15.1	1.485 30.5 69.5	3.680 99.9 00.1

Average Daily Intake of Mineral Elements, and Partition of Outgo Between Urine and Feces—Urine and Feces Together Equal 100 Percent. Intake (upper figure) in Grams; Urine (middle figure) and Feces (lower figure) in Percent of Outgo Experiment V, Table XXI. Period III, 10 Days

Pig No.	Rations	Sodium	Potassium	Calcium	Magnesium	Sulphur	Phosphorus	Chlorine
		Intake Urine Feces	Intake Urine Feces	Intake Urine Feces	Intake Urine Feces	Intake Urine Feces	Intake Urine Feces	Intake Urine Feces
3	Basal ration; glycerophosphates	1.467 62.8 37.2	1.738 61.4 38.6	0.416 20.9 79.1	0.467 66.8 33.2	2.591 77.5 22.5	1.517 28.1 71.9	2.458 99.8 00.2
4	Basal ration; glycerophosphates	1.788 80.7 19.3	2.118 69.9 30.1	0.507 23.7 76.3	0.568 69.0 31.0	3.157 79.4 20.6	1.848 72.0 28.0	2.300 99.7 00.3
5	Basal ration; phosphates	1.857 86.8 13.2	2.200 60.6 39.4	0.516 20.0 80.0	0.591 57.6 42.4	3.283 79.5 20.5	1.922 67.1 32.9	3.113 99.7 00.0
6	Basal ration; phosphates	1.612 84.6 15.4	1.910 63.2 36.8	0.448 13.6 86.4	0.513 62.0 38.0	2.851 79.4 20.6	1.670 73.8 26.2	2.704 99.8 00.2

Average Daily Intake of Mineral Elements, and Partition of Outgo Between Urine and Feces—Urine and Feces Together Equal 100 Percent. Intake (upper figure) in Grams; Urine (middle figure) and Feces (lower figure) in Percent of Outgo Experiment V, Table XXII. Period IV, 10 Days

Pig No.	Rations	Sodium	Potassium	Calcium	Magnesium	Sulphur	Phosphorus	Chlorine
		Intake Urine Feces	Intake Urine Feces	Intake Urine Feces	Intake Urine Feces	Intake Urine Feces	Intake Urine Feces	Intake Urine Feces
3	Basal ration; glycerophosphates....	1.705 58.9 41.1	2.020 56.7 43.3	0.483 21.1 78.9	0.542 66.2 33.8	3.012 77.1 22.9	1 763 36.0 64.0	2 857 99.8 00 2
4	Basal ration; glycerophosphates... ..	1.726 83.1 16.9	2.044 60.0 40.0	0.489 23.9 76.1	0.549 68.8 31.2	3.048 77.6 22.4	1.784 73.7 26.3	2 891 99.8 00.2
5	Basal ration; phosphates.....	1.788 94.9 5.1	2.119 39.0 61.0	0.497 21.8 78.2	0.569 60.9 39.1	3.163 80.1 19.9	1.852 70.9 29.1	2.999 99 7 00.3
6	Basal ration; phosphates.	1.861 92.9 7.1	2.204 49 4 50.6	0.517 18.8 81.2	0.592 64.5 35.5	3.290 81.1 18.9	1.927 71.0 29.0	3.120 99.8 00.2

Average Daily Intake of Mineral Elements, and Partition of Outgo Between Urine and Feces—Urine and Feces Together Equal 100 Percent. Intake (upper figure) in Grams; Urine (middle figure) and Feces (lower figure) in Percent of Outgo Experiment V, Table XXIII. Period V, 10 Days

Pig No.	Rations	Sodium	Potassium	Calcium	Magnesium	Sulphur	Phosphorus	Chlorine
		Intake Urine Feces	Intake Urine Feces	Intake Urine Feces	Intake Urine Feces	Intake Urine Feces	Intake Urine Feces	Intake Urine Feces
3	Basal ration; glycerophosphates	1.714 58.2 41.8	2.031 32.2 67.8	0.486 18.4 81.6	0.545 62.0 38.0	3.027 75.4 24.6	1.772 31.1 68.9	2.872 99.8 00.2
4	Basal ration; glycerophosphates	1.316 78.1 21.9	1.559 76.1 23.9	0.373 22.0 78.0	0.418 69.3 30.7	2.324 79.3 20.7	1.360 79.7 20.3	2.204 99.8 00.2
5	Basal ration; phosphates	1.364 89.5 10.5	1.616 36.1 63.9	0.379 18.8 81.2	0.434 59.9 40.1	2.412 79.3 20.7	1.412 68.7 31.3	2.287 99.7 00.3
6	Basal ration; phosphates	1.868 91.0 9.0	2.213 32.2 67.8	0.519 8.1 91.9	0.594 55.8 44.2	3.303 79.2 20.8	1.934 65.3 34.7	3.132 99.6 00.4

METABOLISM OF SWINE AS AFFECTED BY PHOSPHATES AND GLYCEROPHOSPHATES

Creatinin, Ammonia and Total Nitrogen of the Urine

EXPERIMENT V, TABLE XXIV.

Period and days	Creatinin—Grams				Total nitrogen—Grams				Ammonia N—Grams				Percent N H_3—N			
	Pig 3	Pig 4	Pig 5	Pig 6	Pig 3	Pig 4	Pig 5	Pig 6	Pig 3	Pig 4	Pig 5	Pig 6	Pig 3	Pig 4	Pig 5	Pig 6
Per. I 15 days	Basal ration; no supplement				Basal ration; no supplement				Basal ration; no supplement				Basal ration; no supplement			
	1.4364	1.6251	1.9068	1.6706	23.4685	29.0863	27.2856	25.1928	1.6987	1.5800	1.7541	1.3429	.0724	.0543	.0643	.0533
Per. II 21 days	Glycerophosphates		Phosphates		Glycerophosphates		Phosphates		Glycerophosphates		Phosphates		Glycerophosphates		Phosphates	
	1.5574	1.7829	2.1100	1.8097	.....	16.5092	16 5570	15.1969	.....	1.3894	1.4745	1.3071	.	.0842	.0891	.0860
Per. III 10 days	1.6875	1.8966	2.2302	1.9848	15.1031	19.9128	19.0052	18.1201	1.6414	2.1214	2.1577	1.8211	.1087	.1065	.1135	.1005
Per. IV 10 days	1.8403	2.0000	2.4992	2.14.1	17.5198	20.3707	20.0781	20.4692	2.0092	2.0341	2.1927	2.0332	.1147	.0999	.1092	.0993
Per. V 10 days	1.9087	2.0320	2.3813	2 2820	18.3652	15.5431	15.5539	22.1395	2.0586	1.6344	1.6870	2.2566	.1121	.1052	.1085	.1019
Per. VI 10 days	1.8676	1.9982	2.3095	1.4740	18.6839	15.5989	15.9984	13.0010	2.0450	1.6834	1.7285	1.4205	.1095	.1079	.1080	.1093

DISCUSSION OF RESULTS FROM EXPERIMENT V

The preceding data comprise evidence of the following kinds: (1) gain in live weight in relation to food consumed, (2) weights of parts and organs, (3) chemical accounting for the entire animals, (4) complete balance data on eight chemical elements, (5) digestion coefficients on the proximate food constituents and (6) nitrogen, ammonia and creatinin estimations in the urine. In all these regards mixtures of phosphates of sodium, potassium, calcium, magnesium and iron are compared with glycerophosphates of the same bases. Throughout this exhaustive series of comparisons the relation of the one set of results to the other is so nearly constant that a single general statement will fairly cover all cases. In spite of some possible differences, regarding which we must remain in doubt because of the small number of animals involved, and in spite of considerable individual variation in many of the observations, such a striking similarity prevails in results from the two rations that we must conclude that there is here no evidence to warrant a belief that phosphates and glycerophosphates have different nutritive effects on the gross composition, growth and metabolism of swine; indeed they appear to affect the animals in the same way except that pigs are much more tolerant of glycerophosphates than of phosphates.

While these pigs were fed as much phosphorus in the form of phosphates as they would tolerate, and while they were unable to take calcium carbonate when added to the ration, the pigs lost in the percent of Ca, Mg and P in the skeleton during this experiment; that is, with a low-phosphorus ration it seems to be impossible to make up the deficiency of phosphorus by the addition of readily soluble phosphates in the pure form.

In connection with the mineral balances, a point of interest is the evidence of a marked individual difference in the paths of excretion of phosphorus and sodium, between pig No. 3 and the other subjects of the experiment. This pig retained proportionately as much sodium and phosphorus as did the other three pigs, but excreted very much larger proportions of both in the feces, and correspondingly little in the urine. This pig was seriously disturbed by feeding chalk in the preliminary period (Period I), but recovered when the chalk was left out of the diet; and during the remainder of the experiment it acted normally in every way except for the one particular above mentioned, which may or may not have been related to the previous digestive disturbance.

FINAL DISCUSSION

EXPERIMENTS I—V

From the results of Experiment I it is manifest that phosphorus from orthophosphates, hypophosphites and yeast nucleic acid, when added in the pure form to rations low in phosphorus but capable of maintaining phosphorus equilibrium, may all be absorbed by swine, and may be retained in considerable quantity for at least 10 days. That the retention of each of these compounds may be permanent was, of course, not proven, but seems altogether probable. In the case of hypophosphites this would involve a further oxidation of the phosphorus to the ortho form.

Under the conditions of Experiments II, III and IV, there was some evidence to suggest nutritive superiority of glycerophosphates to orthophosphates, nucleic acid, phytin and hypophosphites, especially in relation to the proportion of muscular tissue and fat in the increase, and the breaking strength and ash per cubic centimeter of volume of the bones, but the evidence was not sufficiently of one sort to establish the facts with certainty.

From the results of Experiment IV we conclude that the mineral constituents and the ether extract of the blood, and not only the amount but also the relative proportions of the bone salts may vary consistently, as affected by the food.

The result of Experiment V was a remarkably uniform and consistent set of observations of many sorts indicating that, at least under the artificial conditions of this experiment, there are no essential differences in the mineral metabolism, the digestibility of the food, and the amount and composition of the growth of swine as affected by phosphates and glycerophosphates.

It seems quite possible that the amount of exercise taken by the pigs, as determined simply by the state of feeling induced by the phosphorus compounds fed, entirely irrespective of fundamental nutritive effects, may have entered into the determination of the relative development and even the composition of the parts.

Such differences in the composition of tissues as were observed might be accounted for as due to variations in the liquid content of the parts, the salts varying accordingly, or to the composition of supporting structures, or unorganized nutritive materials.

While the hypophosphites, nucleic acid and phytin were not subjected to such an exhaustive study as that bestowed upon the comparison of phosphates and glycerophosphates there was no evidence tempting us to go further into the matter, and it is, therefore, our opinion that when added in the usual "chemically pure" forms

to such low-phosphorus basal rations as we used, composed of comparatively simple manufactured products of plant and animal origin, these five compounds do not differ in their nutritive effects upon the gross composition of the growth of swine, except in so far as affected by the relative tolerance of swine toward these preparations, and the consequent influence on the spirits and activity of the animals.

The limit of tolerance of the pigs for glycerophosphates was not reached in any of these tests. Their limit of tolerance of all the other compounds was reached, unmistakably. The pathological states induced inclined us at one time to judge of their nutritive values in the light of these effects, but in this we appear to have been in error.

In order of decreasing acceptability to swine we would rate these compounds, when fed in amounts furnishing equal quantities of phosphorus, in the following order: glycerophosphates, phosphates, phytin, nucleic acid (from yeast) and hypophosphites. The order of the last two is doubtful.

These differences in acceptability were not shown to be directly related to fundamental nutritive effects.

That the differences in acceptability of these isolated compounds similarly affect the foodstuffs in which they are naturally combined seems certainly not to be a fact.

The amount of phosphorus which an animal will tolerate, when added to the ration in readily soluble form, is definitely limited at an amount much less than will be acceptable in its natural relationships in foods.

From the great difficulty experienced in the feeding of yeast nucleic acid and of commercial phytin, as well as the related compound from wheat bran, it is concluded that the isolation of such compounds from natural products alters at least their therapeutic effects in such manner that it becomes impossible to state, from investigations of this sort, on pure compounds, what may be their nutritive values in their natural relationships in common foods.

That the particular organic compounds used in this investigation (nucleic acid, phytin and glycerophosphates) have nutritive values to growing swine, superior to the inorganic compounds used (orthophosphates and hypophosphites) was not shown. No fundamental differences in the nutritive values of the phosphorus compounds studied were established.

No basis, therefore, was discovered for a differentiation between the nutritive values of organic and inorganic phosphorus compounds

generally. It should be borne in mind, however, that no representatives of the two classes, phosphoproteins and lecithins, were included in this investigation, and results obtained under conditions of such rigid experimental control may not accurately represent the facts under optimum, normal conditions of life. These results are not considered to controvert evidence as to specific therapeutic effects of these phosphorus compounds in relations other than those considered in this study.

Even granting the debated superior nutritive value of organic to inorganic compounds of phosphorus, however, it is undoubtedly a fact that the organic phosphorus content of the animal body is a very small part of the total phosphorus, and as certainly true that a very much larger proportion of organic to inorganic phosphorus prevails in the diet of all omnivora and herbivora than in the bodies of these animals; and as for carnivora, the consumption of flesh and bones together would give them approximately the same proportion of organic to inorganic phosphorus in the diet as in their own bodies. It would seem, therefore, that for purposes of growth, the usual diet of animals must contain a sufficiently large proportion of organic to inorganic phosphorus. In this relation, then, the important consideration is simply one of the total phosphorus of the ration, and any such supplemental phosphorus as is to be added to the diet of the healthy, growing animal may be added as inorganic phosphate.

It seems unlikely that, with grown or growing animals, any ration composed from natural foods, and supplying the nitrogen requirement, will fail to furnish enough total phosphorus to maintain phosphorus equilibrium. That many rations compounded from common foods are lacking in the amount of phosphorus essential to maximum retention and growth, however, is as certainly true.

The results of our experiments indicate that the possibility of influencing, to a practical extent, the relative development of tissues and organs of live stock by the addition of isolated compounds of phosphorus to the ration, is probably limited to the density and strength of the bones. It is well known that simple inorganic phosphates, added to a ration of common foods, may be absorbed and retained by farm animals, and, especially in experiments with swine, it has been shown many times over that there is no definite upper limit of phosphate deposit within the bones. This deposit of bone salts may very greatly affect the strength and density of the bones, but the possible increase in external dimensions is slight.

For the purpose of increasing the strength of the bones of growing animals the most practical form in which to administer the

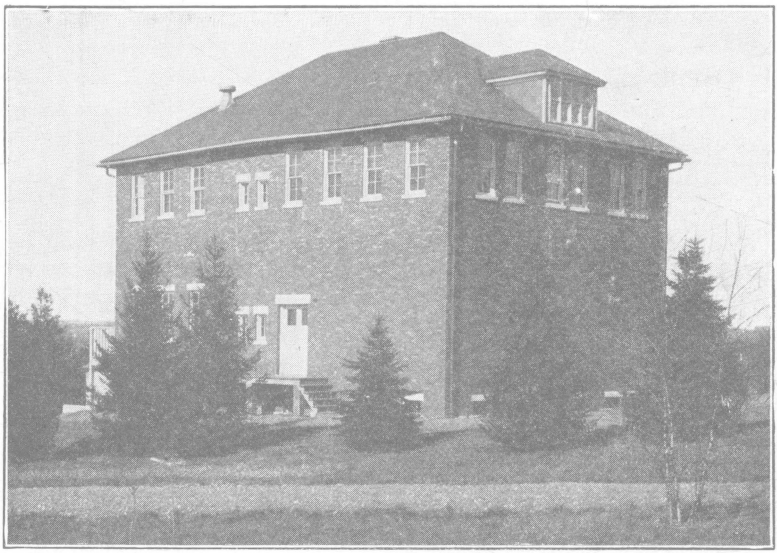
phosphate is probably some acceptable bone preparation. Raw ground bone is not relished by all animals. Precipitated bone phosphates are taken readily by all kinds of farm stock. We are not in position to make comparative statements as to the value, as bone foods, of bone phosphates and raw rock phosphate. That phosphorus may be absorbed by animals, from the rock phosphate, is well known.

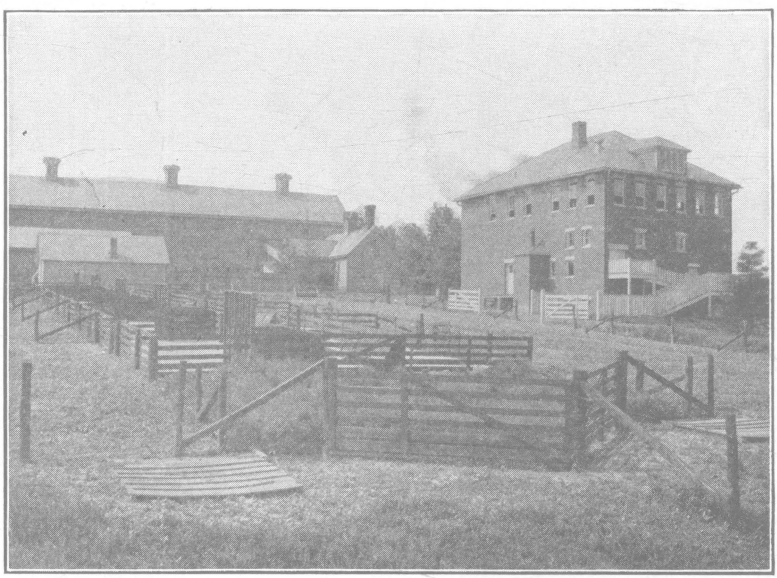
In so far as these results, and those of other investigators whose work we have reviewed, have a bearing on the nutritive or therapeutic effect of inorganic phosphates in human food products, the evidence is that in any such quantities as those in which they are likely to be present they should be regarded as harmless salts which may or may not possess nutritive value, as determined by the requirements of the animal, and by the other constituents of the diet.

The addition of comparatively small amounts of corn to rations compounded from simple manufactured products of plant and animal origin may enhance the nutritive value of such rations to an extent out of proportion to the amount of corn added, the particular constituent of the corn responsible for the improvement being as yet unknown, but quite possibly a vitamine.

One apparent fault in the plans of these several experiments is the low calcium content of the rations. This defect, however, was due, not to oversight, but to the fact that it appears to be impossible to add to a ration very low in phosphorus, any considerable amount of calcium carbonate without causing profound digestive disturbance. We attempted, time after time, to correct the above-mentioned defect in the rations by the addition of this salt, but failure was our invariable reward. No such result follows the administration of calcium carbonate in a ration of natural foods of normal phosphorus content. In our judgment, the subjects of these experiments suffered from deficient intake of phosphorus, even though the particular compounds administered were generally given nearly (and sometimes quite) to the limit of toleration, and though the phosphorus balances were positive. This phosphorus deficiency seems to have been rendered still more acute by administering calcium carbonate, perhaps through limiting the reabsorption of once-excreted phosphorus by combination with the same,—since increased calcium and phosphorus were found in the feces at the same time that urinary phosphorus decreased. This would imply that phosphorus compounds, other than calcium phosphate, are involved in essential ways in the normal digestion of food.

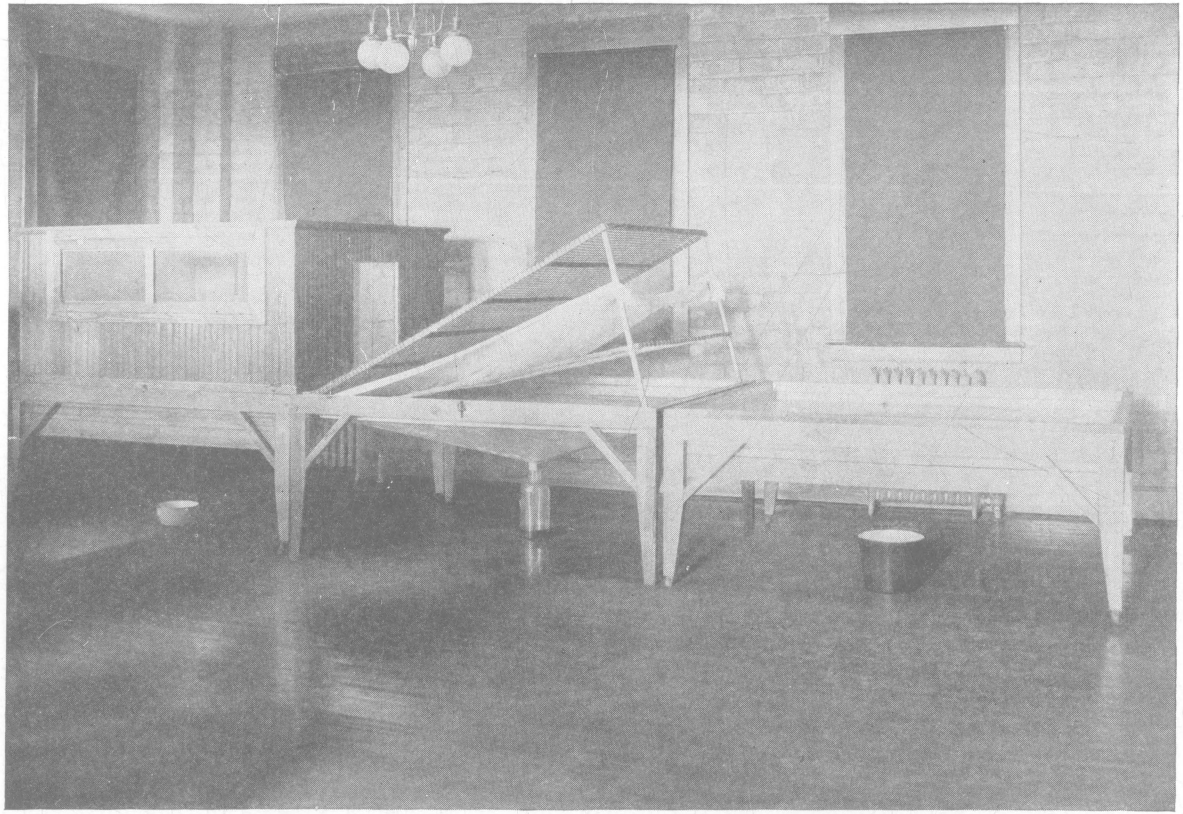
Thus calcium and phosphorus were both deficient in the rations, but the animals possessed quite a limited toleration of either in the form of pure salts. While the rations were so low in phosphorus that the bones were quite deficiently nourished, we were unable to give more than 25-40 percent of the total phosphorus in the forms to be compared. Attempts to increase the mineral base of the rations through the addition of potassium citrate and soda were also unsuccessful.



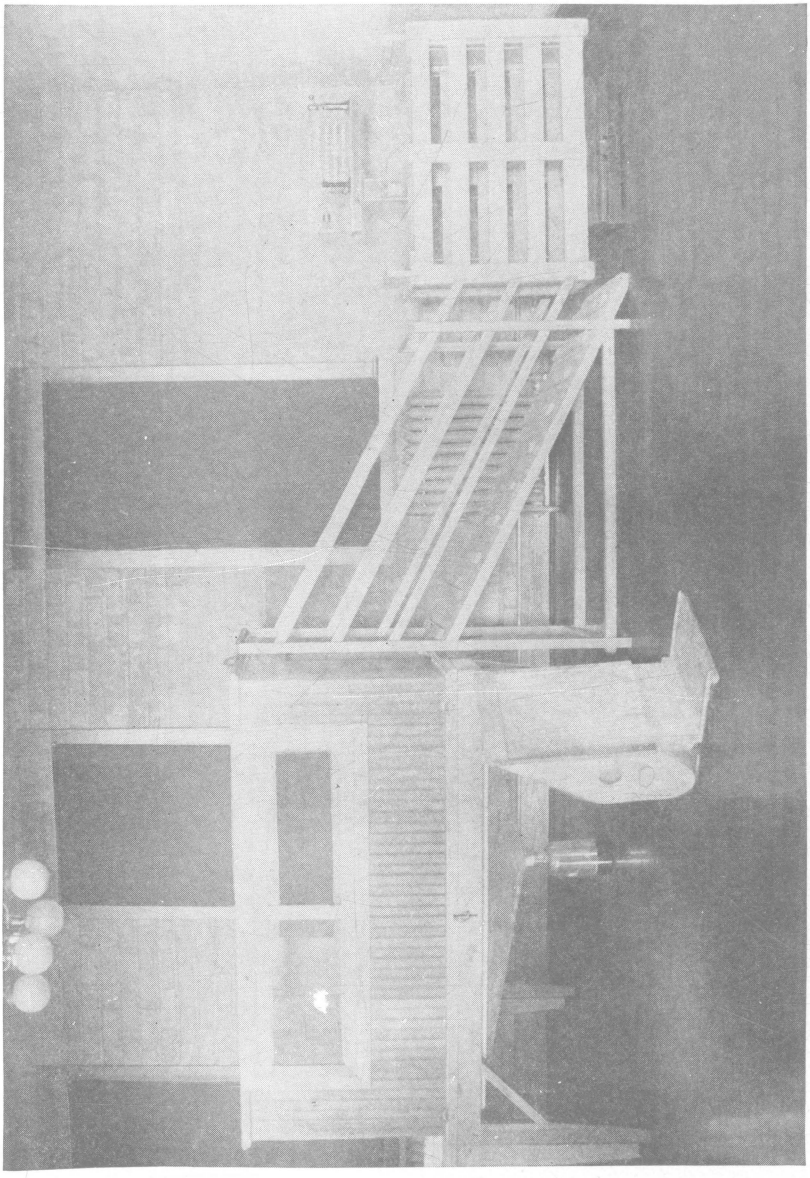


Nutrition experiment building, front and rear views. This building is used for metabolism, slaughter, refrigeration and meat curing experiments.

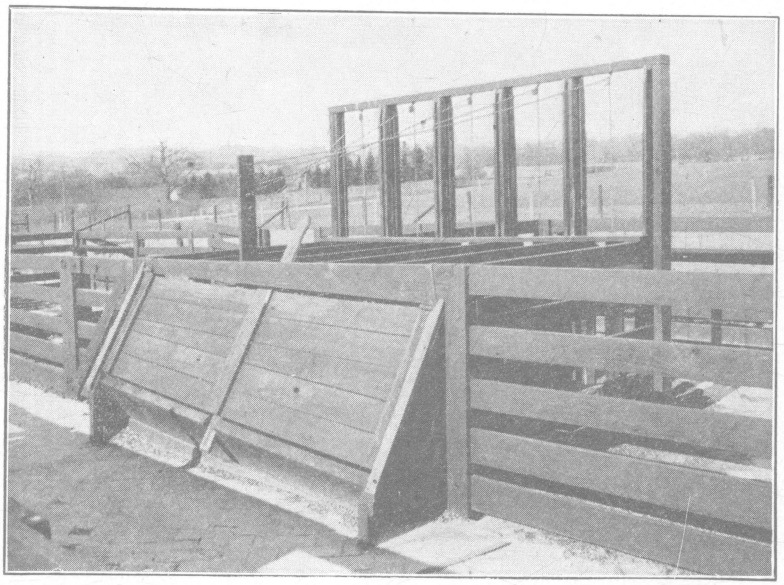
Metabolism crates for use with swine. This apparatus allows the pig to move about with freedom, and at the same time provides for the separate collection of urine and feces.

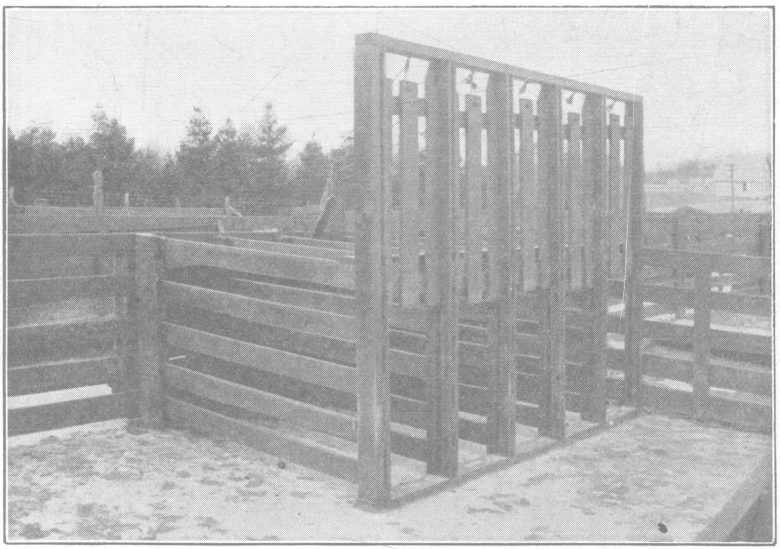


Metabolism crate. The pig and the top part of the crate have been shoved over onto the cleaning table; the screens and cloth are elevated to show relations of one to another.

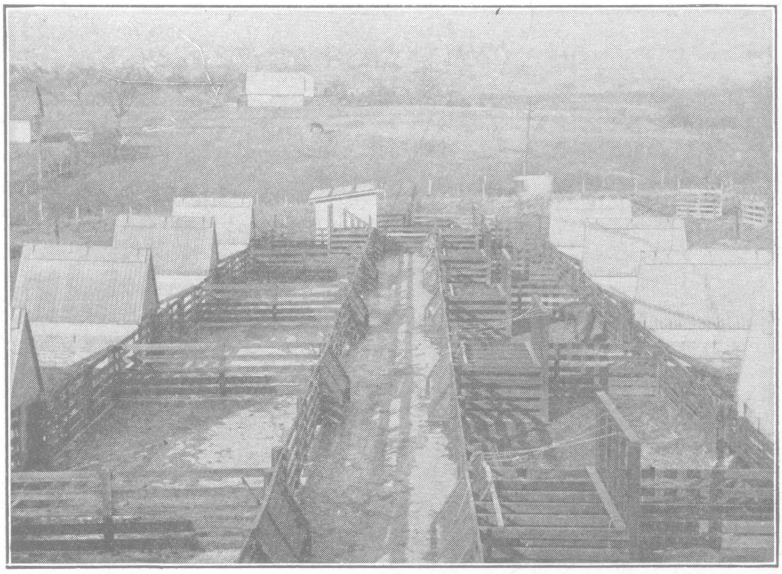


Metabolism crate, weighing apparatus and feed box.

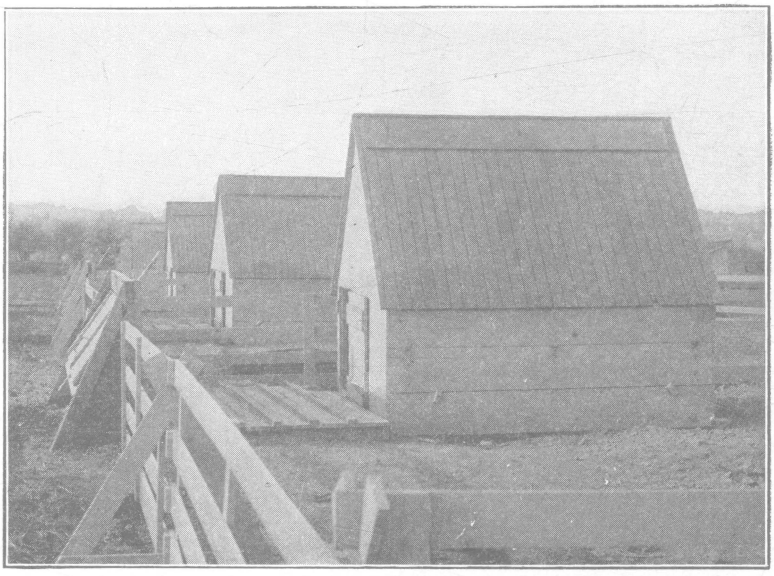




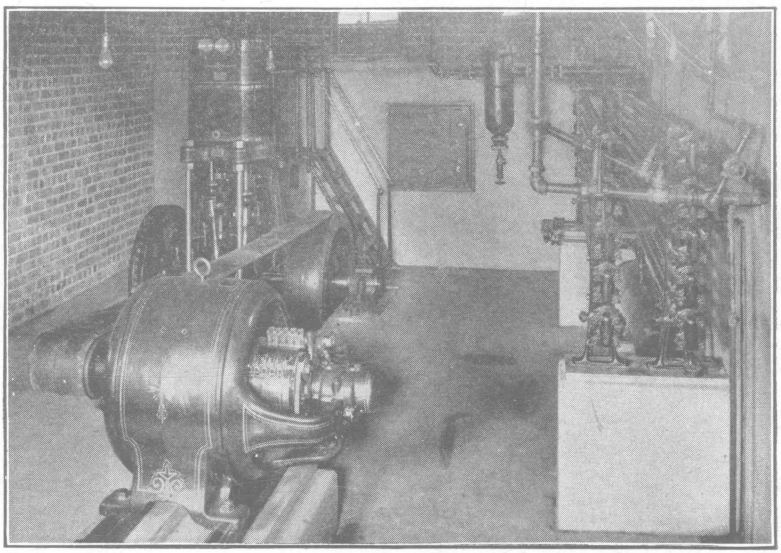
Pens for individual feeding of swine; front and rear views.



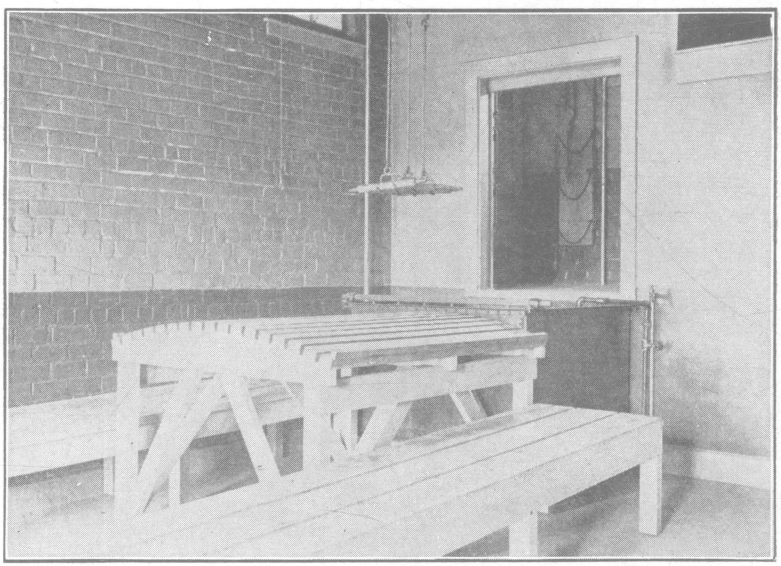
Paved lots for experimental feeding of swine.



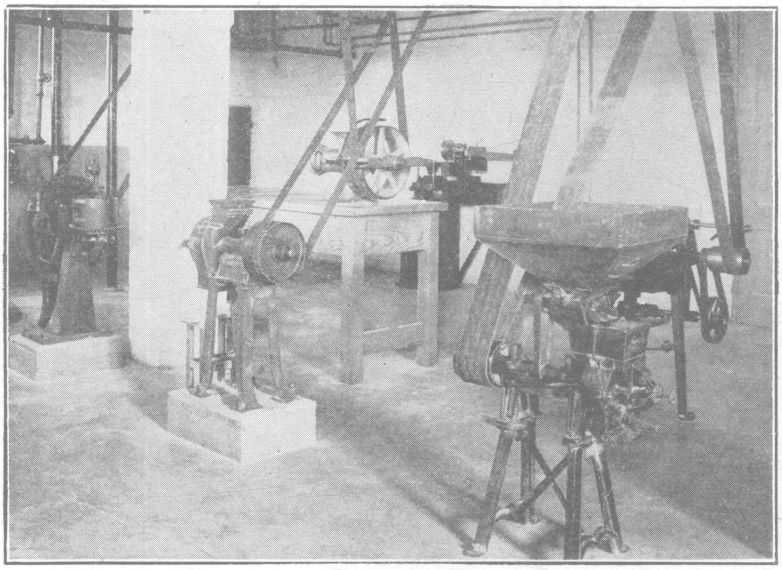
Movable houses and fences for handling breeding swine.

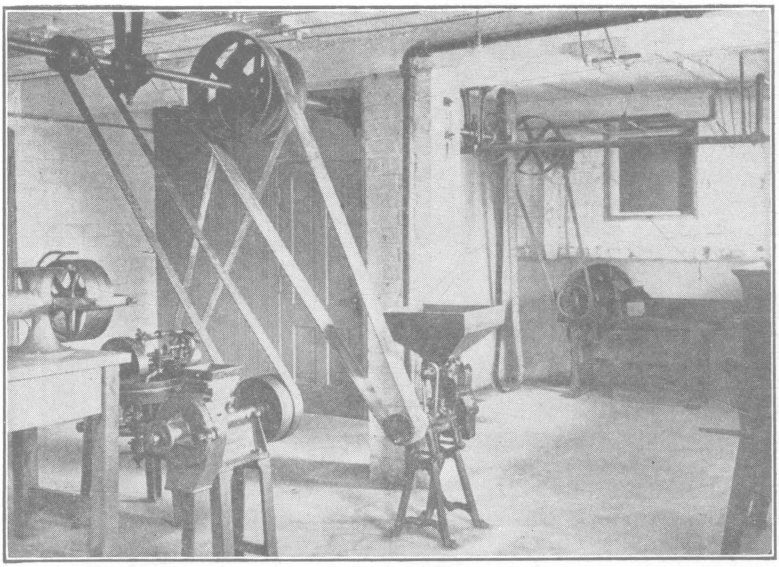


Ice machine; capacity twenty tons.

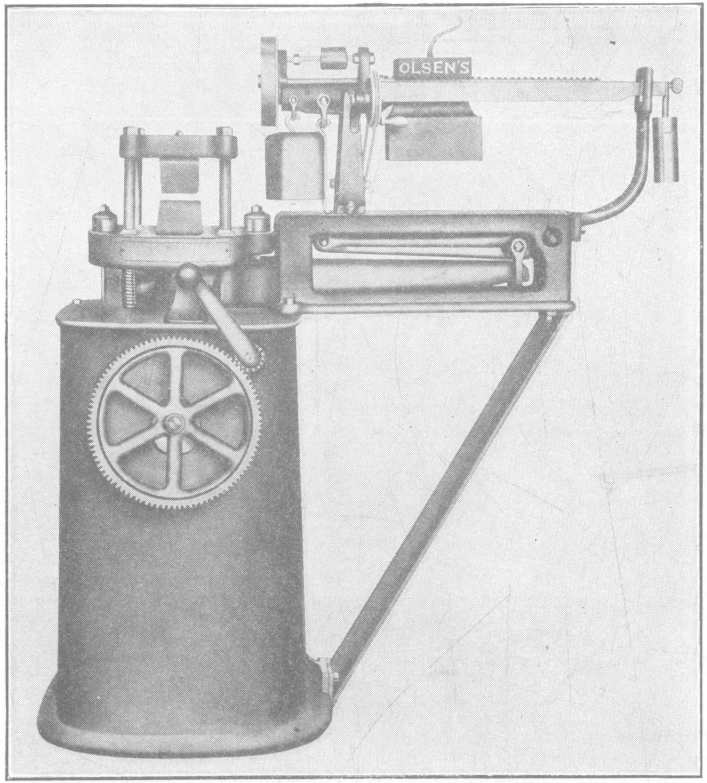


Sticking pen, scalding vat and scraping bench for swine.

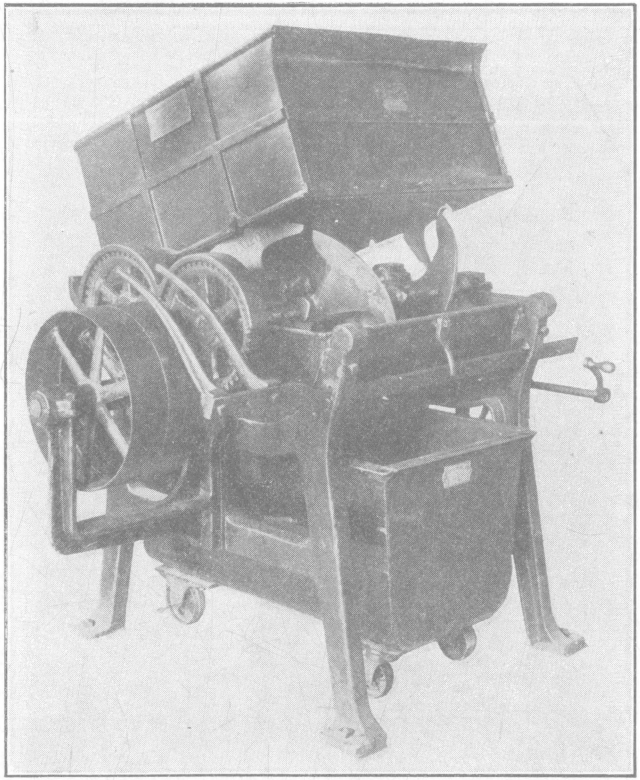




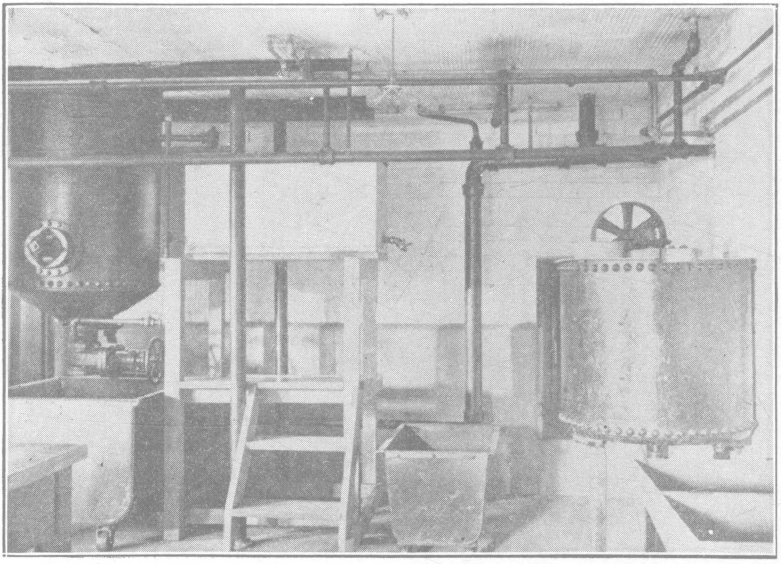
Views in machinery room. Equipment for cutting, grinding and mixing feed, meat, bone, etc.



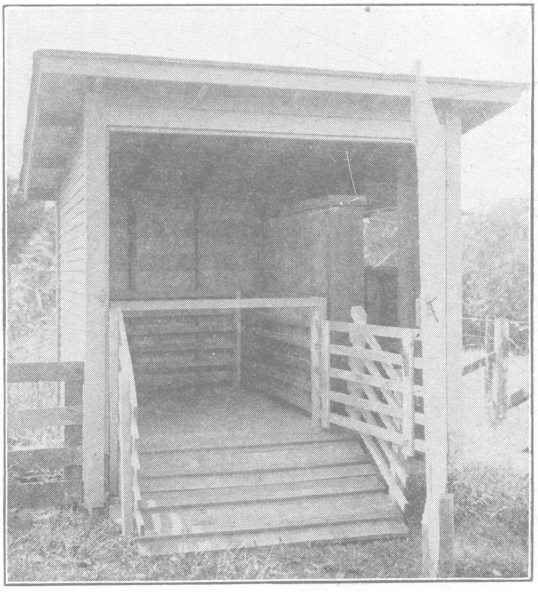
Testing machine. Used to determine effects of food on strength of bones.



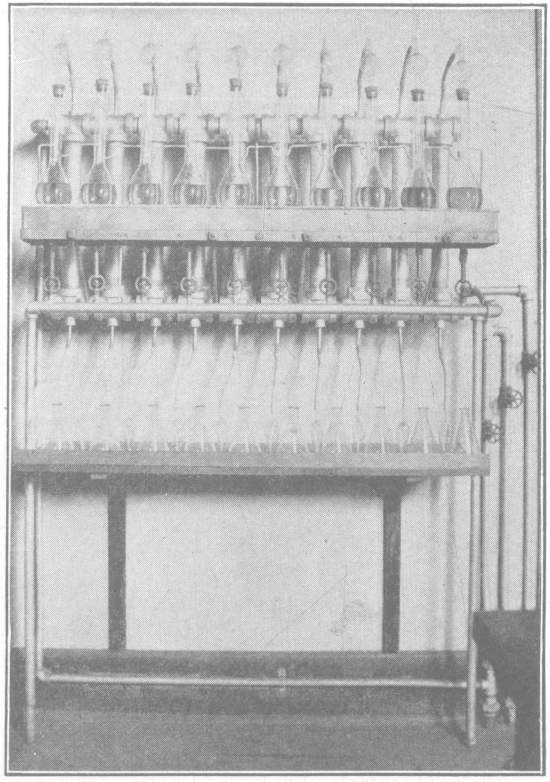
Meat mixer. Used in preparation of samples of meat for chemical analysis.



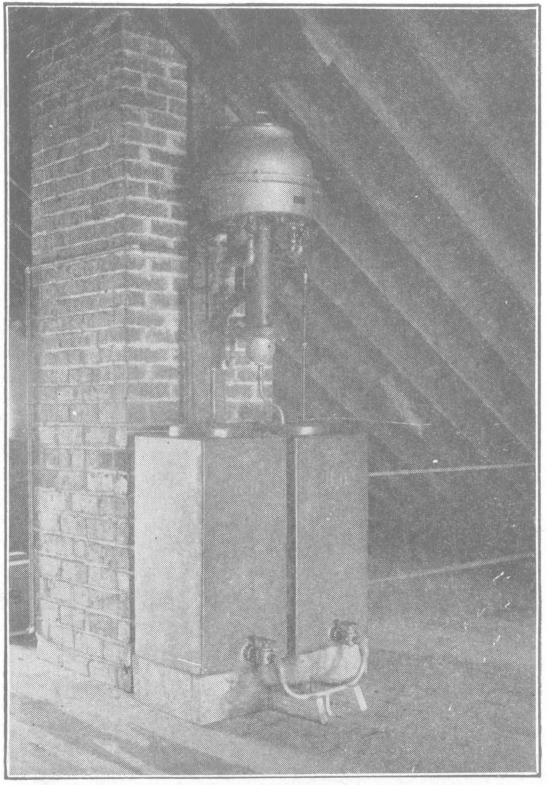
Apparatus for rendering out fat.



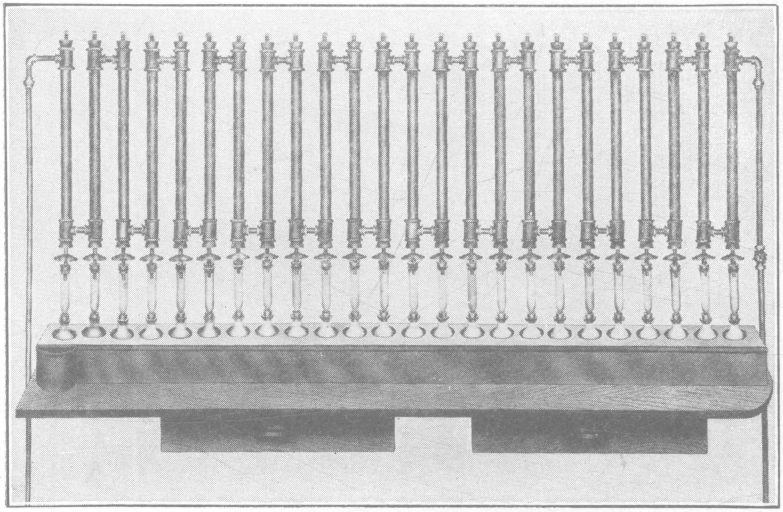
Scale house, for weighing swine.



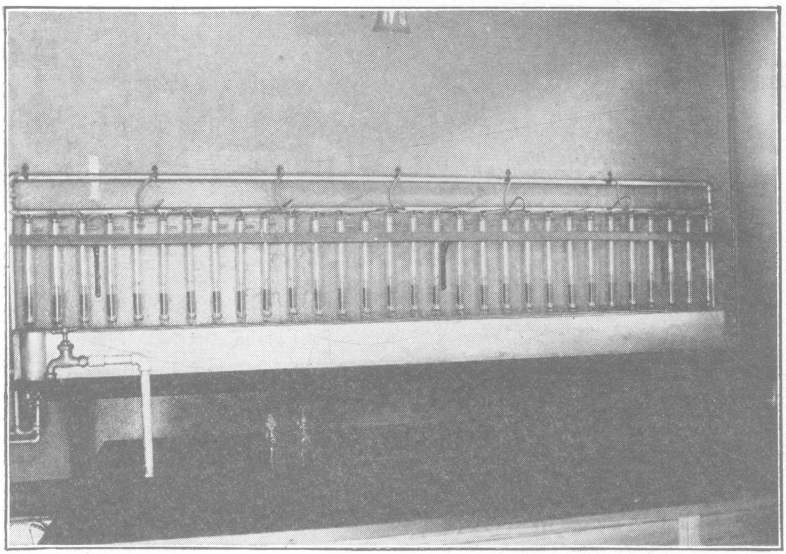
Ammonia still. Apparatus used in nitrogen estimation.



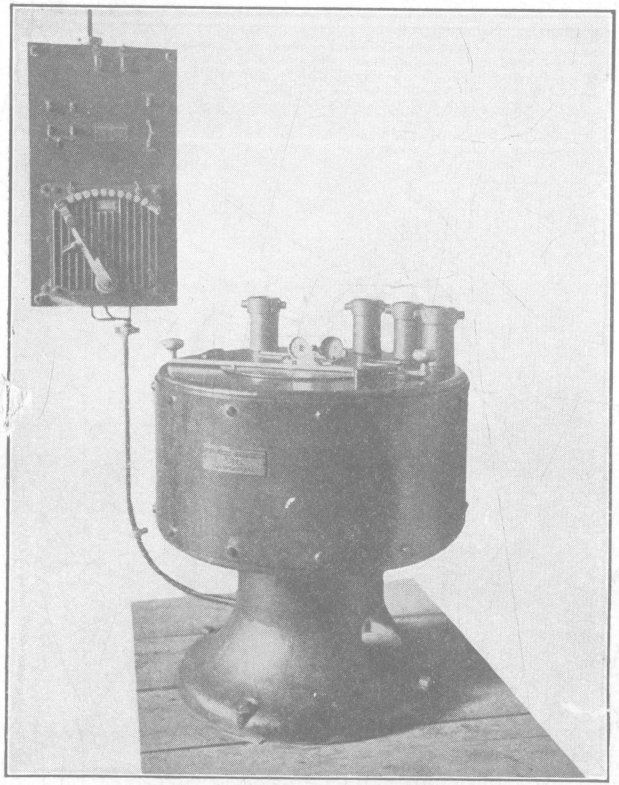
Water still. In mineral metabolism studies all animals receive distilled water to drink.



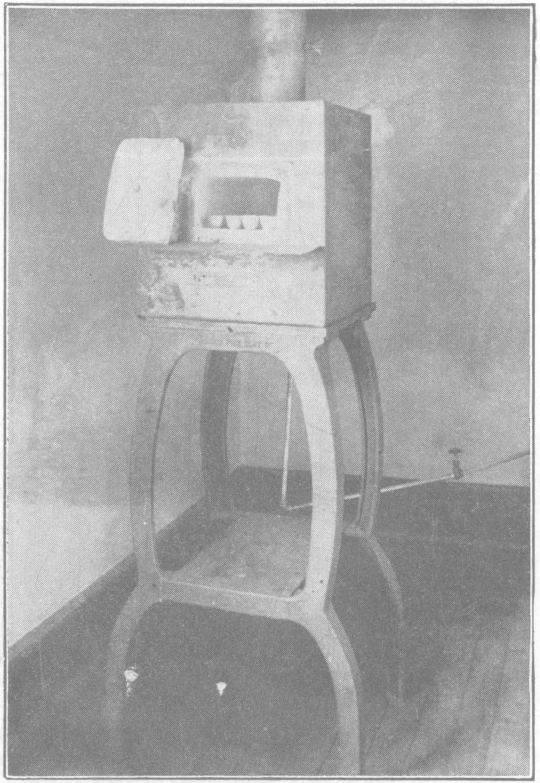
Ether extraction apparatus used in estimation of fat.



Alcohol-ether extraction apparatus used in extraction of phosphorus compounds from animal tissues.



Centrifuge. Used to facilitate difficult filtration of plant and animal extracts.



Muffle furnace. Used in mineral analysis.